A Formal Agent-Based Personalised Mobile System to Support Emergency Response

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ABSTRACT

Communication may be seen as a process of sending and accepting information among individuals. It is a vital part of emergency response management, sharing the information of situations, victims, family and friends, rescue organisations and others. The obtained contextual information during a disaster event, however, is often dynamic, partial and may be conflicting with each other. Current communication strategies and solutions for emergency response have limitations - in that they are often designed to support information sharing between organisations and not individuals. As a result, they are often not personalisable. They also cannot make use of opportunistic resources, e.g. people nearby the disaster-struck areas that are ready to help but are not a part of any organisation. However, history has told us such people are often the first responders that provide the most immediate and useful help to the victims.

On the other hand, the advanced and rich capabilities of mobile smartphones have become one of the most interesting topics in the field of mobile technologies and applied science. It is especially interesting when it can be expanded to become an effective emergency response tool to discover affected people and connect them with the first responders and their families, friends and communities. At present, research on emergency response is ineffective for handling large-scale disasters where professional rescuers could not reach victims in disaster struck-areas immediately. This is because current approaches are often built to support formal emergency response teams and organizations. Individual emergency response efforts, e.g. searching for missing people (inc. families and friends), are often web-based applications that are also not effective. Other works focus on sensory development that lacks integrated search and rescue approaches.

In this thesis, I developed a distributed and personalisable Mobile Kit Disaster Assistant (MKA) system that is underpinned by a formal foundation. It aims at gathering emergency response information held by multiple resources before, during and after a large-scale disaster. As a result, contextual and background information based on a formal framework would be readily available, if a disaster indeed strikes. To this end, my core contribution is to provide a structural formal framework to encapsulate important information that is used to support emergency response at a

personal level. Several (conceptual) structures were built to allow an individual to express his/her own individual circumstances, inc. relationships with others and health status that will determine how he/she may communicate with others.

The communication framework is consisting of several new components: a rich and holistic Emergency Response Communication Framework, a newly developed Communication and Tracking Ontology (CTO), a newly devised Emergency Response Agent Communication Language (ER-ACL) and a brand-new Emergency Response Agent Communication Protocol (ER-ACP). I have framed the emergency response problem as a multi-agent problem where each smartphone would act as an agent for its user; each user would take on a role depending on requirements and/or the tasks at hand and the above framework is aimed to be used within a peer to peer distributed multi-agent system (MAS) to assist emergency response efforts.

Based on this formal framework, I have developed a mobile application, the MKA system, to capture important features of EM and to demonstrate the practicalities and value of the proposed formal framework. This system was carefully evaluated by both domain experts and potential users of targeted user groups using both qualitative and quantitative approaches. The overall results are very encouraging. Evaluators appreciated the importance of the tool and believe such tools are vital in saving lives – that is applicable for large-scale disasters as well as for individual life-critical events.

DEDICATION *(if any)*

First and foremost, all praise to Allah for providing me with the strength, perseverance, and wisdom to have this work done. There are a number of people without whom this thesis might not have been written, and to whom I am greatly indebted.

I would like to express my deepest gratitude and thank my supervisor, **Dr Yun-Heh Chen-Burger**, for her constant support and intellectual guidance to me throughout my years in the Heriot-Watt University, UK.

I would like to thank especially my lovely wife and my co-traveller, **Norshita Mat Nayan,** our dear children **Asfa Farhana** and **Muhammad Anas Farhan** who always be with me and for everything they did to support me. If not for their dedication and sacrifices, I would not have come up to this level in life.

Finally, many thanks to my parents, **Hassan Rashid** and **Khairiah Sallehuddin** as well as all my family for their continued support. I would also like to thank the people who have been part of my life in Edinburgh while I've been there. Last but not least, I would like to acknowledge all my colleagues and friends, who kept this period of study as enjoyable as possible.

DECLARATION STATEMENT

(Research Thesis Submission Form should be placed here)

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Published Work

Parts of the work presented in this thesis have been published in the proceedings of international conferences and refereed workshops. The corresponding publications are listed below. I also include a reference to the parts of this thesis based on the corresponding work.

International Conference

- M. K. A. Hassan and Y. H. Chen-Burger, 'Communication and Tracking Ontology Development for Civilians Earthquake Disaster Assistance', Proc. ISCRAM 2016 Conf. – Rio Janeiro, Brazil, May 2016 Tapia, no. May, 2016.
- M. K. A. Hassan and Y. H. Chen-Burger, 'A Communication and Tracking Ontology for Mobile Systems in the Event of a Large Scale Disaster', Smart Innov. Syst. Technol., vol. 58, no. March, pp. 119–137, 2016.
- M. K. A. Hassan and Y. H. Chen-Burger, 'ER-Agent Communication Languages and Protocol for Large-Scale Emergency Responses', in Agents and Multi-Agent Systems: Technologies and Applications 2018, pp. 134–143, 2018
- Poster Presentation in SICSA DemoFest 2016, "Mobile Kit-Disaster Assistant (MKA): A Mobile System to Assist Relief in Large-Scale Disasters**".**
- Poster Presentation in SICSA DemoFest 2018, "A Formal Agent-Based Personalised Mobile System to Support Emergency Response".

Chapter 1 – Introduction

1.1 Overview

Adequate communication is vital for any Emergency Response scenarios for any disasters regardless of its size of either small or large. Immediate reliefs are carried out by the First Responders who mitigate unexpected and dangerous occurrences and relieve people and/or the environment from the impact. From relieving natural disasters to hazardous events or transportation incidents, Emergency Response Team (ERT) are formal organizations or groups of volunteers who have adequate training to save people in the state of emergency. In addition, Emergency Response (ER) may refer to services provided by the teams, as well as plans and actions taken to respond to an emergency situation. A critical measurement of the successfulness of ER is the response time that often determines the chances of safe recovery of victims affected by disasters. It is defined by the time that it takes for emergency responders to arrive at the scene of an emergency after the emergency response system has been activated. For this reason, all countries in the world, Inc. World Health Organisation (WHO) [1] and almost all big organisations and health-and-safety critical industries e.g. oil & gas industries and chemical factories [2] need an ERT within the organisation to mobilise and execute their ER plans quickly.

For instance, one of the major types of disasters is Earthquake. It is capable of causing grave devastations, including large numbers of fatalities, injuries, people missing and displacements. Previously, in the province of Sichuan, China, the earthquake in 2008 in China killed at least 69,000 people, injuring more than 374,000 and left about 4.8 million people homeless. The Haiti earthquake in January 2010 had caused over 200,000 fatalities, 300,000 injuries and left over 1 million people homeless. Another example is when the earthquake hit the Pacific Ocean and created a subsequent tsunami in Japan in March 2011 that at least 20,000 people died, 465,000 were displaced, 2500 went missing, and a further 28,000 drowned in the ocean. It is estimated that it had cost the Japanese and the global economy $360 billion US dollars. This had generated an unprecedented loss to the Japanese people, the environment and global economy.

Unfortunately, earthquakes are not rare events. According to US Geological Survey (USGS), the frequency of the occurrences of severe earthquakes is beyond one's imagination - on average, there is one occurrence (Magnitude of 6 or above) every year since 1990**, Section 2.2** gives more detailed earthquake information between 1990 and 2014. The main impact of earthquake disasters regularly occurs immediately after the main earthquake events are finished. The human cost is at the highest when it is caused by collapsing building, explosions, tsunami, fire and landslides, etc. Some victims are missing; others are trapped and died because rescuers could not find them in time. Speedy and accurate communicating with victims and tracking them in such situations are vital to saving lives. However, past experiences have proven this is not always possible and locating victims becomes a primitive (Inc. people calling out verbally or using sniffer dogs that may not be able to locate people far away or buried deeper in the ground) and sometimes impossible task. However, such grave situations can be improved using advanced mobile device technologies, by using its communication and location-based identification capabilities that victims' locations and their well-being can be communicated in a timely manner. Unfortunately, when existing, such tools are often developed for organisational use only that individuals do not have access to them. However, first responders that help at the first instance are often members of the public who happen to be at the disaster struck locations that provided the most important first relief from danger.

The US Federal Emergency Management Agency (FEMA) has defined the emergency management as "the managerial function charged with creating the framework within which communities reduce vulnerability to hazards and cope with disasters." [3]. A comprehensive emergency management refers to "the development of handling emergency tasks in all phases such as mitigation, preparedness, response and recovery and in connection with all types of disaster agents by coordinating the efforts and resources of all players such as non-governmental organizations (NGOs), government agencies and private sectors involved" [4]. With the experience of a disaster such as Katrina Hurricane in 2005 and Southeast Asia tsunami in 2004, FEMA has reinforced the need for the development of a comprehensive approach to emergency management [5]. Furthermore, the stakeholders (government agencies and world community) of emergency response found it increasingly difficult to coordinate and respond to emergency situations, due to the complexity of communication between them. The result of this has increased the number of deaths, delay in access to basic needs and slower recovery time [6].

The objectives of this thesis are therefore aimed to contribute to the improvements of communication methods for emergency response using a sound, structural and systematic approach. I have reframed the Emergence Response problem as a multi-agent problem where each participant is modelled as an agent. It is also a user-centric view of the problem, where communication can be personalised.

As a result, I have created a structural theoretical framework, Emergency Response Communication Framework, that includes several formal components, including a new Emergency Response Communication and Tracking Ontology (CTO) to store contextual/domain knowledge, a new Emergency Response Agent Communication Language (ER-ACL) to support the actual communication, and a new corresponding Emergency Response Agent Communication Protocol (ER-ACP). To demonstrate the practicalities and value of this theoretical framework, I have developed a distributed agent-based MKA system that should encompass the following main aspects:

- Communication – information and knowledge prior to disasters struck is embedded in the MKA system to support two-way communications, the tool also ensures safe delivery of messages;
- Tracking People – applying integrated mobile smartphone sensor such as Global Navigation Satellite System (GNSS) and multi-gesture signals in MKA system. These sensors will automatically send appropriate information during communications between victims, family, friends and rescuers;
- Alerting – making use of alerting programme such as Earthquake Early Warning System (EEWS) and feeding information from early warning system (EWS) to provide combined information and smartphone alarms.

- Peer to Peer (P2P) connectivity - The MKA system is able to work either online or offline depends on internet connection availability.

1.2 Problem Definition and Research Gap

Due to the complexities and dynamism in emergency response, knowledge management and representation and ontologies can play a very useful part in providing rich, timely and effective information support. It would cover a lot of information background during the disasters, for instance, survivors' locations, shelters availabilities information and communication content with victims and survivors. More importantly, to convey individual information (of victims) in a personalised manner. Currently, all of the matured large scale of disaster rescue tools and systems are developed and deployed by governmental and NGO agencies. There is no suitable personalised mobile application system that helps individuals and those at risk. For instance, for any large-scale disaster, it means different things to the different people - for some, it does not mean much (as they are not affected); for others, it may mean the matter of life and death.

In addition, although victims are at the centre of any emergency rescue missions of any large-scale disasters, they are often left out of the equation and cannot take a more pro-active role. It is often unclear as of where they are, how they are, and what they really need (e.g. are they trapped, are they hurt, do they have any medical condition that needs immediate attention, do they need any special type of assistance, how urgent is it?). Without clear information, how rescue workers may carry out rescue tasks efficiently and in the most appropriate ways? This pointed out the acute need for communicating with the victims in real time in a disaster, but there is not such an ER tool available for individual use.

Another grave but very common issue of rescue missions is to ask for help from professional rescue bodies or rather the lack of it – because, during a disastrous event, telecommunication is often interrupted or even non-functional, that external rescuers could not reach the needed people quickly. In such cases, volunteers from local communities can be and often are the main helping force. Having a sustainable team of volunteers embedded within a vulnerable community is very useful, both for the community and ERT. These members are local residences. They will have local knowledge and can play a critical role in disaster response. It would be ideal if some types of ER communication tool can be offered to them to enhance their rescue work. In addition, in the event of telecommunication network disruptions, normal communication mechanisms, Inc. landline, mobile and smartphones would no longer function. Could there be alternative but structural and reliable communication mechanism be deployed? Such communication mechanism should ideally be personalisable to support individual needs and can be deployed at an ad-hoc basis.

1.3 Research Objective, Processes and Tasks

The main objectives of this research are therefore to solve or at least to alleviate the above communication problems that occur during disastrous events. My objectives in this research are in support of the Sendai Framework [7], an international standard adopted by the United Nation Office for Disaster Risk Reduction (UNISDR) in the year 2015 in Sendai, Japan. I refer to Sendai Framework's second target below:

"Substantially reduce the number of affected people globally by 2030, aiming to lower the average global figure per 100,000 between 2020-2030 compared to 2005-2015"

To address this problem, I have developed a Mobile Kit Disaster Assistant (MKA) system based on a rigor formal framework, and the purpose is to provide effective communication and to assist the coordination among victims, communities, rescuer workers and organisations who are involved directly or indirectly during and just after earthquake disasters, thereby providing speedier recovery and relief to the victims as much as possible. During a disastrous event, the MKA mobile communication system allows family, friends, volunteers or organisations to use their smart devices to find out relevant information about the victims, such as where their exact locations are, their well-being at the time, their family contacts and even background information, such as names, chronic disease (if any) or blood type, if made available to them.

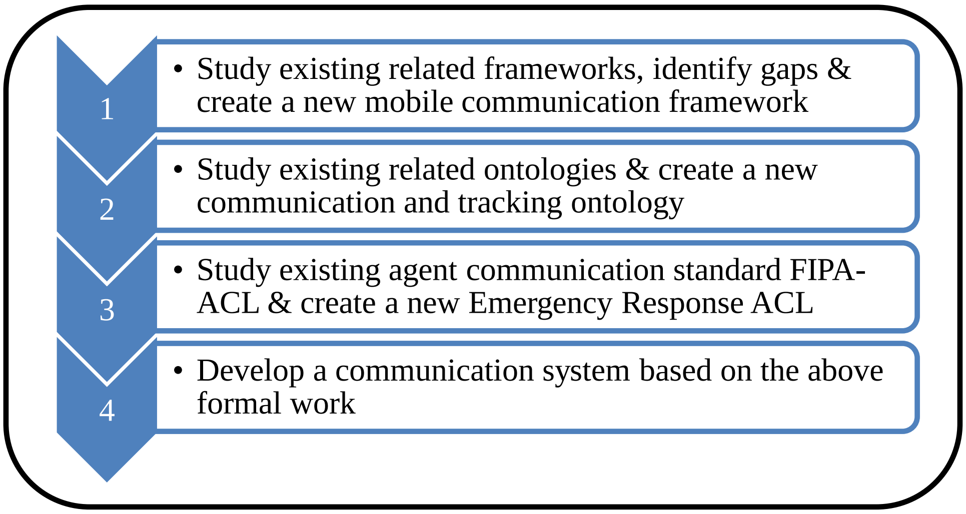


Figure 1: Research Process

The research process diagram in **Figure 1** sees the ER communication problems as problems of semantic interoperability in a multi-agent system - where ontologies will support semantics interpretation in a communication framework and where ER Agent Communication Language (ER-ACL) underpinned by the ontologies will be used for communication in smart mobile device applications. Such mobile applications should help rescuers to easier find victims near them and also survivors can easier find the nearest agencies/people who can help them. Therefore, the tasks of this research were:

1. Based on existing but informal standard emergency management framework, to extend and develop a suitable mobile communication framework that may be automated to help people in events of disaster.

2. Based on relevant existing ontologies, to extend and develop suitable ontologies (where appropriate) for tracking people/victims whom may be trapped or lost and also to help the communication between them and their helpers/rescuers, e.g. in the events of earthquake disasters.

3. Based on the Foundation for Intelligence Physical Agents' standard, (FIPA) Agent Communication Language, to develop a new and suitable Agent Communication Language that is specialized to support Emergency Response to help solve complex communication issues during disasters.

4. To use the above ontologies in a mobile application and instantiate it with appropriate knowledge to form a knowledge base for retrieving and managing

knowledge at the run-time in the domain of emergency response for communication and tracking people, e.g. during an earthquake.

5. Based on the above formal work, to provide a mobile application and communication mechanism to help missing people/victims in order to monitor them using real-time information as well as developing suitable communication strategies to provide timely support during disasters.

6. To provide a mobile application with suitable user interfaces that are user-friendly for most ages (Inc. the younger and older generations) and naive users who may not be familiar with smart phone technologies.

7. To ensure seamless communication, even in the events of telecommunication interruptions and disruptions. To accomplish this, P2P communication methods will be investigated and implemented where suitable.

1.4 Main Contributions

This thesis has the following major contributions:

1. A new innovative communication framework is specialised to support emergency response that is enabled by a knowledge-rich mobile app that can be personalized to suit individual user's needs using formal representations.

2. A new, rich and expressive Communication and Tracking Ontology (CTO) for describing emergency situations and contextual information of emergency response and rescue related tasks - that is an extension and integration of existing related ontologies such as FOAF, Weather, Disaster and Time ontology.

3. A new rich and specialised Agent Communication Language for Emergency Response (ER-ACL) that is suitable for communicating, conversing and tracking individuals and when only limited resources are available, Inc. limitations posed by mobile phone batteries, and interrupted or intermittent telecommunication availabilities.

4. A new, effective and relatively reliable Emergency Response Communication and Messaging Protocol (ER-ACP) that is suitable for communication in large scale disastrous events. Its three-way handshaking protocol making it suitable for rescuers to monitor the victim's well-being status live and reliably.

5. Reducing the possibility of a congested network after a large-scale disaster by using a Peer to Peer (P2P) communication mechanism and a randomised, time-based message sending mechanism.

6. Preserving smartphone batteries in the event of large-scale disasters by reducing and managing the frequency of message sending based on necessities. This principle and the corresponding procedure have been implemented using Android's native built-in functions that is available to all Android mobile phones.

7. An effective mobile smartphone application (the MKA system) that is based on experts' evaluation and advice, potential users' usability testing with a suitable background.

1.5 Research Questions

In order to achieve the aforementioned objectives, it is necessary to find suitable answers to the following research questions:

1. What types of communication framework are useful for communicating and tracking people to support emergency response in the events of disaster?

2. Is ontology-based data useful for integrating heterogeneous data and to support communication with individuals and tracking them using mobile apps, and to provide warning and instructions, to help evacuation and/or rescue missions?

3. What types of communication models are useful in such scenarios? What knowledge/information needs to be stored and transmitted, whom it needs to send to, when to send, how to send and how often? What is the suitable format

and vocabularies? How one can make sure that messages are being delivered to the right people?

4. What is the suitable knowledge representation for describing the disaster events and rescue missions? What events should be included to provide appropriate support?

5. What types of communication solution may be useful to help track people who are trapped or missing in the disaster?

6. What types of telecommunication technology will be able to function during a disaster even when the Internet connection is cut-off, interrupted or function only intermittently? Is Peer to Peer (P2P) communication mechanism useful? If so, how this may be utilised?

1.6 Important Issues for the Communication of Emergency Response

Communication is key to assist any emergency response, especially in the events of large-scale disasters where lots of lives are at stake. Effective communication allows on-site volunteers and rescuers to quickly and accurately find victims, thereby allowing them to plan and carry out rescue tasks orderly and in a timely fashion. This would avoid (large number of) fatalities that may otherwise occur. Communication is also essential to keep families, friends, social and medical carers informed, therefore providing suitable physical and mental support in time of need.

In addition, even with the availabilities of new technologies such as smartphones, there remains a large number of victims that would die, go missing or not being discovered and rescued in time due to poor communication. Via an ontological based approach, this research allows the user to record personal information ahead of disasters and so can inform relevant personnel about their predicaments in a concise and timely fashion when needed and as appropriate.

On the other hand, although mobile smartphones are one of the top multi-functional devices which is capable of supporting a broad range of applications to provide communication aids in large scale disasters, the potential of such mobile technologies has not been fully exploited to become an effective emergency response tool which is a loss.

However, in the words of [8], the smartphone with the worst battery life in 2016 was Sony Xperia XA whose battery could only stand for a maximum of seven hours while the best one could only stand for about 22 hours. The presumption of an average 50 percent battery power left in mobile phones while a disaster occurs is something which ought to be taken very seriously to assist victims in large-scale disastrous situations if the mobile app is capable of managing the phone usage, e.g. by regulating the number of times messages are sent as well as the length of messages, that is, limiting/optimising mobile phones' use, thus extending their battery life.

Some existing mobile applications have been developed to provide disaster-related information, such as earthquake alerts and historical records, including scales and locations. The government would also broadcast warning messages, e.g. earthquake warning via text messages, to the public [9]. These applications or sent messages were not based on personal needs or even locations, because they are broadcasted to all users, including those who are not affected! This may and had created unnecessary confusion and panic in some people.

Other problems of such applications are, e.g., it does not provide instructions or even suggestions to affected individuals either directly or indirectly – they do not know each individual's circumstances, therefore, there is no way they can provide accurate helpful instructions. They also do not make use of personal communication features, such as those available via mobile phones. This is a great miss of opportunity, as smartphones are commonly used by many. Therefore, there is a need and opportunity to address all of these above problems and to provide functions in one tool such as a smartphone and not via many separate heterogeneous instruments and systems.

It takes time to form professional ERT and since they are often situated remotely, it can take quite some time to arrive at the disaster-affected area. Earthquakes can severely damage facilities such as roads, buildings, the internet network, disrupt telecommunication and cell-phone signal masts that communication may stop functioning all together; whereas other information resources such as people who live nearby can provide immediate help and rescue victims before a formal organisation can assist them. In addition, there is also a lack of systematic live monitoring of victims (i.e. the status of their well-being) and potential help resources (e.g. availabilities of shelters or hospital bed).

This research, therefore, aims to help people communicate in affected disaster areas and improve the communication with and tracking of victims by taking a victim-centric approach, with the assumption that many individuals in affected area use or will use a smartphone in the future. Also, very important is the ability to connect victims and the support network, Inc. the appropriate medical team, family and friends, rescuers, etc., to gain the much-needed help. The ultimate aim is to provide personalised support and in an accurate and timely manner. The proposed approach reported here should answer a lot of questions raised in this session.

1.7 Thesis Outline

The core of this thesis is divided into 6 Chapter. In the following, the thesis is outlined by summarising each chapter.

Chapter 1: Introduction. I introduce and state the problem studied in this thesis. Emergency response related information system is currently managed by an organisation which gathers data for the particular organisation and reported to ERT. In the same way, I found there is a lack of community-based support system to help victims in a critical situation. I study a complex communication issue to allowing me to develop a MKA system for public use.

Chapter 2: Literature Review. I review the areas which build the foundations of my research. I focus on Knowledge Representation and system related technologies. I give more focused background at the beginning of chapters 3, 4 and 5. I begin each of these chapters with a review and a discussion of the state of the art in the corresponding research domains, respectively emergency response knowledge representation and evaluation for MKA system.

Chapter 3: Formal framework for the Personalised Mobile ER-Communication. The Conceptualisation of communication-related to develop the foundation. In order to develop a communication structural design for MKA system for mobile apps, I need to design my communication framework, an ontological model and agent communication specifying how the domain can be structured. This model and framework provide a set of anchor points, on which emergency response information can be hooked. This chapter also describes my new propositional framework, ontology and agent communication language. Using a set of real-world emergency response related user needs, I then develop an MKA mobile system and evaluate how wide this range of my foundation framework information and system in chapter 4.

Chapter 4: Mobile Kit Disaster Assistant Application. I now build a mobile app for public used during the disaster and emergency response. In this chapter, I discuss the process of development, requirement and system design as well as the snapshot of the system. The system develops based on the conceptual foundation I develop in chapter 4.

Chapter 5: Evaluation of the conceptual and empirical foundation and i.e. Communication framework, CTO Ontology, ER-ACL and usability of the MKA mobile apps. This chapter describes my evaluation methodology, using as a basis a set of real-world emergency response-related user needs and evaluating how well MKA mobile apps backed by my frameworks could be used to answer these needs. I evaluate using this methodology and reach a measure for the range of emergency response-related information it covers.

Chapter 6: Conclusion and future work. I summarise the contributions of this thesis and outline directions for future work.

Chapter 2 – Literature Review

2.1 Introduction

In this chapter, I review many areas which constitute the foundations of my research. I review six main areas, background and record of a large-scale disaster in **Section 2.2**, current ER project in **Section 2.3**, ontology knowledge representation in **Section 2.4**, communication framework in **Section 2.5**, agent communication language in **Section 2.6** and mobile app system and technologies in **Section 2.7**. The more detailed and focused background is given at the beginning of the next thesis chapters.

2.2 Background of Natural Disaster

In the last 20 years, many types of the disasters occurred around the globe, such as eruption, fire, flood, forest fire, hailstorm, hurricane, landslides, mudslide, sinkholes, storm, tornado, tsunami, typhoon, volcano and wildfire [10]–[15]. Flooding has been the most common natural disaster with 43% ahead from all disaster events recorded in [16] reported by UN Office for Disaster Risk Reduction. Whereas Epidemiology of Disasters Centre Research recorded at least than 3,062 natural flood disasters between 1995 and 2015.

After the recent flood in Japan in July 2018 [17], where 200 people died, there were investigations into the possibilities of providing public emergency pagers to people living in high-risk flood areas, in order to understand the life status of victims. The main motivation for such devices is affordability (low cost). However, such devices provide only limited functions, i.e. to send alerts and receive a simple response (e.g. to find out whether the victim is still alive).

Furthermore, the second most frequently occurring disaster is storms, at 28%, while earthquakes categorised more than 6 magnitudes were third with 8%. The following **Figure 2** shows the most frequently occurring natural disasters between 1995 and 2015.

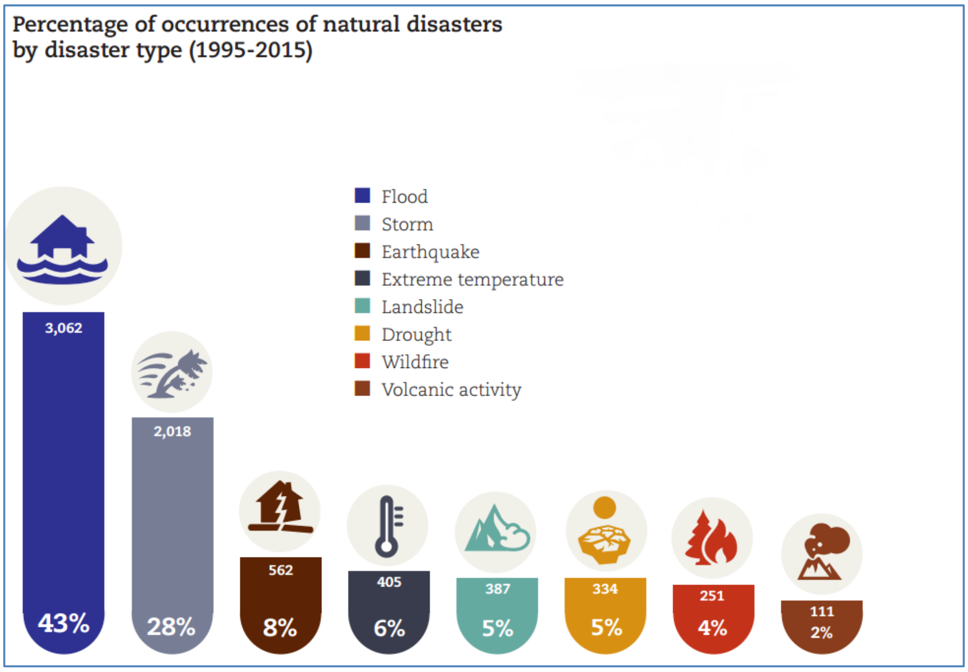


Figure 2: Percentage of Occurrences of Natural Disasters by Disaster Type, Source adapted from [16].

Among them is the earthquake which happens to be one of the disasters that are not well-understood, as it may occur without any warning sign and nobody, including geologists, can say categorically the place and time it may occur [18]. By definition, "earthquakes occur when stress is suddenly released along faults in the earth's crust" [19]. The continuous movement of tectonic plates results in the build-up of stress within the rocks on both sides. When the stress within the rock becomes greater than what the rock can withstand, it will be let loose. The seismic energy that is released moves through the earth as well as along its surface as waves and the waves are responsible for the shaking of the ground that is experienced during earthquakes. **Figure 3** below indicates the effect of an earthquake of intensity 8 or above which is categorised as level 5 (danger level) by [19].

Danger level 5 (very high danger)	
Effects	High likelihood of severe damage to buildings, even to very stable structures. Buildings may also collapse. The earthquake is felt very strongly, people are alarmed and lose balance. These effects correspond to an intensity of VIII or greater*. This level of intensity may be reached with earthquakes with a magnitude of around 5.4 or greater.
What to do	Take cover, be ready for aftershocks. For further information see What to do during an earthquake.
Description Measurement and forecast values	• Felt strongly, high likelihood of widespread and severe damage to buildings. • *Intensity VIII or greater*

Figure 3: Earthquake Danger Level Intensity 8 or Greater**.** Source adapted from [19].

In this research, I am interested in working on earthquake disasters because of the tremendous damages that can be created by it and the effects on human lives, not to mention the large economical cost. Some relevant facts are listed below:

1. In total, 49 earthquakes had happened in 24 years from 1990 – 2014 (as recorded in [20]);
2. 57% of earthquakes are categorized as large earthquakes with 7.0 magnitude and above;
3. Near the East Coast of Honshu, Japan in the year 2011 shown one of the largest earthquakes with a magnitude of nine;
4. Top fatalities were 316,000 during a Haiti earthquake in 2010;
5. 60,000 people went missing during an Indian Ocean earthquake in 2004;
6. More than 100 people went missing during a New Zealand earthquake in 2011 (As recorded in [21]);
7. More than 1,000 people are still missing during a Nepal earthquake in April 2015 (As recorded in [22]);
8. Diplomats are finding it hard to trace missing because many backpackers do not register with their embassies when they arrive in the country (mention in [22]);
9. Up to 72-hours after an emergency occurred is the golden hours for rescue. Lives can be saved in greater chance if discovered within these golden hours (as stated in [11]);
10. More than 260 people were dead, mostly in Pakistan, after a magnitude of 7.5 earthquake hit north-eastern Afghanistan in 2015 (as stated in [23]);

In **Figure 4**, the Earthquake Reports from United States Geological Survey (USGS) [20] recorded severe earthquakes (with a magnitude more than 6.0) and their impacts since 1990. The Haiti earthquake of the year 2010 indicated a large number of fatalities with 316,000 people and many more have not been traced (missing) today. While earthquakes can destroy infrastructure and kill people, aftershocks can cause even more damage to an area. It is, therefore, possible to classify the impacts of an earthquake as short and long-term impacts on the social, economic and environmental spectrums.

Largest Earthquakes					Deadliest Earthquakes				
Year	Date	Magnitude	Fatalities	Region	Year	Date	Magnitude	Fatalities	Region
1990	16-Jul	7.7	1,621	Luzon, Philippine Islands	1990	20-Jun	7.4	50,000	Iran
1991	22-Apr	7.6	75	Costa Rica	1991	19-Oct	6.8	2,000	Northern India
1991	22-Dec	7.6	-	Kuril Islands	1991				
1992	12-Dec	7.8	2,519	Flores Region, Indonesia	1992	12-Dec	7.8	2,519	Flores Region, Indonesia
1993	08-Aug	7.8	-	South of Mariana Islands	1993	29-Sep	6.2	9,748	India
1994	04-Oct	8.3	11	Kuril Islands	1994	06-Jun	6.8	795	Colombia
1995	30-Jul	8	3	Near Coast of Northern Chile	1995	16-Jan	6.9	5,530	Kobe, Japan
1995	09-Oct	8	49	Near Coast of Jalisco Mexico	1995				
1996	17-Feb	8.2	166	Irian Jaya Region Indonesia	1996	03-Feb	6.6	322	Yunnan, China
1997	14-Oct	7.8	-	South of Fiji Islands	1997	10-May	7.3	1,572	Northern Iran
1997	05-Dec	7.8	-	Near East Coast of Kamchatka	1997				
1998	25-Mar	8.1	-	Balleny Islands Region	1998	30-May	6.6	4,000	Afghanistan-Tajikistan Border Region
1999	20-Sep	7.7	2,297	Taiwan	1999	17-Aug	7.6	17,118	Turkey
2000	16-Nov	8	2	New Ireland Region, P.N.G.	2000	04-Jun	7.9	103	Southern Sumatera, Indonesia

Largest Earthquakes					Deadliest Earthquakes				
Year	Date	Magnitude	Fatalities	Region	Year	Date	Magnitude	Fatalities	Region
2001	23-Jun	8.4	138	Near Coast of Peru	2001	26-Jan	7.7	20,023	India
2002	03-Nov	7.9	-	Central Alaska	2002	25-Mar	6.1	1,000	Hindu Kush Region, Afghanistan
2003	25-Sep	8.3	-	Hokkaido, Japan Region	2003	26-Dec	6.6	31,000	Southeastern Iran
2004	26-Dec	9.1	227,898	Off West Coast of Northern Sumatra	2004	26-Dec	9.1	227,898	Off West Coast of Northern Sumatra
2005	28-Mar	8.6	1,313	Northern Sumatra, Indonesia	2005	08-Oct	7.6	80,361	Pakistan
2006	15-Nov	8.3	-	Kuril Islands	2006	26-May	6.3	5,749	Java, Indonesia
2007	12-Sep	8.5	25	Southern Sumatera, Indonesia	2007	15-Aug	8	514	Near the Coast of Central Peru
2008	12-May	7.9	87,587	Eastern Sichuan, China	2008	12-May	7.9	87,587	Eastern Sichuan, China
2009	29-Sep	8.1	192	Samoa Islands region	2009	30-Sep	7.5	1,117	Southern Sumatra, Indonesia
2010	27-Feb	8.8	507	Offshore Maule, Chile	2010	12-Jan	7	316,000	Haiti
2011	11-Mar	9	20,896	Near the East Coast of Honshu, Japan	2011	11-Mar	9	20,896	Near the East Coast of Honshu, Japan
2012	11-Apr	8.6	-	off the west coast of northern Sumatra	2012	06-Feb	6.7	113	Negros-Cebu region, Philippines
2013	24-May	8.3	-	Sea of Okhotsk	2013	24-Sep	7.7	825	61km NNE of Awaran, Pakistan/td>
2014	01-Apr	8.2	6	NW of Iquique, Chile	2014	03-Aug	6.2	729	near Wenping, China

Figure 4: Earthquakes and Fatalities from the Year 1990 – 2014 (more than 6 magnitude size) by USGS. Source adapted from [20].

2.3 Current Emergency Response Projects

2.3.1 Earthquake Early Warning System

Early warning system (EWS) is a technology designed to predict and mitigate the harm of natural and human-initiated disasters and other undesirable events. Early warning systems for natural hazards include those designed for earthquakes, flood, tsunamis, tornadoes or landslides. The system uses a variety of communication tools, including email, broadcast faxes, television and phone calls to alert local, state and federal authorities and the media about urgent threats and necessary actions.

Many of research centre organizations all over the world were putting their efforts to investigate especially in the domain of disasters and emergency response such as United State Geological Survey (USGS), ATOS Global Emergency Management (Europe), Disaster Mitigation Research Centre (Nagoya University, Japan), Humanitarian Aid and Civil Protection (Europe), Pacific Earthquake Engineering Research Centre (California Institute of Technology, US), Care International (UK) and US Environmental Protection Agency (US). These organizations were studying in multi-area such as training and mitigation project. However, they are also doing the research related to IT technology such as Earthquake Early Warning System (EEWS), information system and mobile apps in emergency response during disasters.

EEWS is for the rapid detection of earthquakes, real-time assessment of the shaking hazard and notification of people prior to shaking. Warning times range from a few seconds to a few minutes depending on the location and how big the earthquake is. The further people away from the epicentre, the more warning time they have. The bigger the earthquake, the stronger the shaking at greater distances. An early warning should tell how strong the shaking will be at a particular location, and how long until that shaking starts (the warning time). There are several of EEWS developed and used in a different country. It still under testing and on-going development such as ShakeAlert, PRESTo, UrEDAS [24], Elarms [25], [26], EDAS-MAS [27] and etc.

ShakeAlert system was developed in 2006 by USGS [28] which is one of the pioneers in EEWS study. This system used to monitor and alert people through PC, mobile devices or engineering application after shaking waves generated by an earthquake are expected to arrive at the location. This technology has been demonstrated, begin with informed selected users in California by sending test notifications in January 2012. EEWS detects earthquakes using the California Integrated Seismic Network (CISN), an existing network of about 400 high-quality ground motion sensors. The system will calculate the value of P (Felt Wave) and S (Damage Wave) after the earthquake hit. According to USGS, P waves are moving fast and be the first wave arrived at the destination, followed by S wave which stronger impact than P and can cause great damage. Within a single second, ShakeAlert detects the location and severity of the earthquake to warn people of its presence and sending a notification to personal computer and mobile. The warning message can be transmitted instantaneously, whereas the shaking waves from the earthquake travel through the shallow layers of the Earth at speeds of one to a few kilometres per second (0.5 to 3 miles per second).

2.3.2 Smart Emergency Response System (SERS)

Smart Emergency Response System (SERS) was created by [29] and started in the year 2013. The system covered six stations/sections where each station manages by a different research team. **Figure 5** shows the station and research team in SERS project.

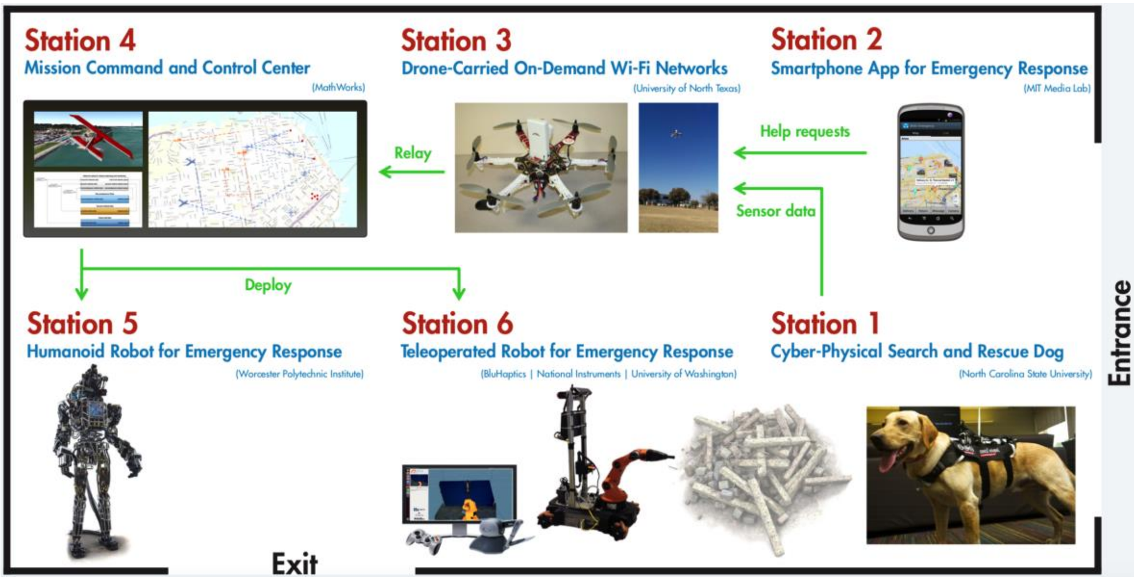


Figure 5: Booth Map in the Smart Emergency Response System (SERS). Source adapted from [30].

Overall, the SERS system provides survivors of an emergency such as a natural disaster and the emergency personnel with the information to locate and assist between them. One of the stations in SERS is Smartphone Apps studied by MIT Media Lab where the application is able to support, allow affected people to offer and request basic needs in a disaster situation. SERS research allows submitting help requests to the mission centre. This study was implemented in MATLAB where it connects all station such as first responders, mobile smart apps, search-and-rescue dogs, humanoid, robots, autonomous drones, and ground vehicles. The command and control centre optimize the available resources to serve every incoming request and generates an action plan for the mission. The Wi-Fi network is created on the fly by the equipped with antennas. In addition, the autonomous drones, such as rotorcrafts, fixed-wing aeroplanes, and ground vehicles are simulated with Simulink and visualized in a 3D environment (Google Earth) to unlock the ability to observe the operations from a personal computing machine.

2.3.3 Emergency Management System (EMS) on Web

Recently, Emergency Management System has attracted many interests. The golden time [31] is a time measurement within which time frame victims would have a higher chance to survive, i.e. if they are rescued soon after the incident occurred. This kind of system was developed for the organisation i.e. police department [32] where the system has general functionality such as calling, messaging, alarm, location and decision making. Another study was undertaken by COMSATS Institute of Information Technology in Pakistan [33] and it centred on GIS, web-based as well as application used in the emergency management system (EMS), particularly in the analysis of GIS data of transport systems, location of incidents, ambulance and observation teams, hospitals, fire brigades, police, etc. In their words, analysis of spatial data can be undertaken by scrutinising past incidents using the server manager of ArcGIS located at the backend which is designed for all the interaction services of the basic map in ASP.NET that are capable of responding to all manner of things needed by the responder using their smart android phone.

Four major sensors of android cell phone are incorporated into the application, namely Accelerometer, Barometer, GNSS and Thermistor. This sensor technology is highly significant when a disaster happens. Regarding the function of accelerometer, when a user fails to respond to a message more than three minutes after it pops up, such message will be repeated thrice. If the user is still unable to respond to the message that popped up, then the fourth time, the mobile phone will send a message automatically: *"Need Some Help, Please Rescue Me"* to the person designated by the owner of the mobile phone as their SOS. This form of system is extremely helpful when an individual is in such conditions as a heart attack, abnormally high blood pressure, trauma, driving a car or riding a bike alone, migraine (mental distress), asthma attack and lots more. With the creation of a system for managing life-threatening situations using Web platform, Android, and GIS, it is obvious that merging multiple technologies can help lives as well as properties of people whose lives and properties are in danger.

2.3.4 European Commission Disaster Monitoring Research Projects

Global Disaster Alerts and Coordination System (GDACS) is a collaboration project between United Nation, The European Commission and Disaster Managers [34]. GDACS system is a near real-time alert system to monitor natural disasters and improving early warning communication in partnership with their agencies. GDACS was developed in 2004 with fully automatic 24/7 alert system which gathers data about natural events such as earthquakes, tsunamis, tropical storms, floods and volcanoes. It is a web-based platform for natural disasters, such as earthquakes, tsunamis, floods and cyclones. The system is able to send automatic alerts via e-mail, fax or SMS to the ERT. GDACS combines the information of the event, the population in the affected area and the vulnerability of that population to derive an alert level that indicates the probability for a catastrophic situation with needs for international humanitarian intervention. GDACS also offers a platform for structured information exchange between responders and coordinators, thus facilitating decision-making.

Besides that, another system developed is the European Flood Alert System (EFAS), a monitoring system and forecasting floods across Europe where it provides complementary, flood early warning information up to 10 days in advance. In addition, they also established a European Forest Fire Information System (EFFIS) which supports the services saddled with the responsibility of protecting forests against fires in the EU nations and providing the European Parliament and the European Commission services with up-to-date and dependable information regarding European wildland fires.

2.3.5 Emergency Services Command and Control Systems

ATOS, an IT digital services firm [35] situated in France was offered a comprehensive solution for emergency management, which ensures optimal utilization of resources, decreases response times and above all saves lives. With the command and control system of the emergency services, this company was able to provide the biggest medical emergency coordination centre in Europe situated on more than 500 square meters and providing comprehensive medical care to more than 3,500 patients on a daily basis. The system is capable of assigning any emergency incident to a certain resource, including an ambulance, a rapid response vehicle or a helicopter and transmits to them an emergency message. Each of the vehicles that has something to do with this project is provided with a computer tablet which shares with the coordination centre a high-speed wireless connection that is available there. This makes it possible for the first responders to have adequate information regarding the incident that has been sent to them to attend to and also permits them to have access to the medical history of a patient via system connections to the health record system which is electronic in nature. It also makes it possible for the first responders to send the report of their assistance, blood pressure, ECG and the readings of carbon monoxide. Thus, from time to time, hospital resources are mobilized waiting for the arrival of patients.

2.4 Ontology Knowledge Representation

2.4.1 Introduction

In this section, I discuss what is knowledge representation and its use in my research. I review the areas which constitute the foundations of emergency response in disaster domain. Two main areas have been reviewed, knowledge representation **Section 2.4.2** and the ontology in **Section 2.4.3**.

2.4.2 Knowledge Representation

Knowledge is the understanding of a subject area. There are differences between data, information and knowledge. I describe all terms as below:

1. Data – Primitive, verifiable facts. Example: name of organisation involved in a disaster relief operation.
2. Information - Analysed data, or data within a context. Example: The organisation that is frequently involved in disaster relief is "ERT" or "Red Cross".
3. Knowledge - Analysed information that is often used for further information deduction. Example: Since the government knows the organisation involved in disasters, the government may consider enlarging this organisation by increasing the number of workers or volunteers.

In order for mobile device agents to help with emergency response in disaster issues, we need a framework in which knowledge can be made explicit. Such a framework allows devices to automatically process knowledge, and to share knowledge unambiguously. The basic problem of knowledge representation is then the development of a sufficiently precise notation for representing knowledge [36].

The current generation of information systems for emergency response are based on information provided by large and diverse collections of sensors, including information supplied by human volunteers or crowdsourcing [37].

2.4.3 Ontologies

Ontology in information technology is the working model of entities and interactions in some particular domain of knowledge practices or in simple words, it is "the activity of planning." On the other hand, in artificial intelligence (AI), according to AI expert [38], an ontology is "the specification of conceptualizations, used to help programs and humans share knowledge." In this usage, an ontology is a set of concepts such as events, things, and relations that are specified in some way in order to create an agreed vocabulary for exchanging information.

In 2009, The Guelph Ontology Team (GOT) has conducted research in knowledge engineering (KE) (particularly in ontologies) and software engineering (SE) with a focus on flexibility, reusability and efficiency [39]. Several existing competing methodologies with regard to how an ontology may be built, there is not a single right way to build an ontology. Furthermore, there is not a (de facto standard) Disaster Relief Ontology, although separated related ontologies may be combined to create an initial version. I investigate the concepts and features addressed and the representation methods used in the research related to ontology.

Quite early on, a number of researches recognised and have argued that the field of emergency response can benefit from ontologies and the Semantic Web technologies. Ontologies have been proposed and developed ad-hoc in some applications. For instance, the *PeopleFinder system* was developed ad-hoc to store information of missing persons in a bid to help searching tasks during the Katrina hurricane [6]. *PeopleFinder* apps employed a data model of missing people expressed in XML, the People Finder Interchange Format (PFIF). Another relevant research for the use of ontology is a web-based application blog (SEA-EAT) that has been set up during the Asian tsunami in 2014. It is an information exchange system for searching missing persons, requesting for help and providing news updates [6]. This blog has been proposed to use ontology-based for a knowledge base for sharing and extracting searching for information.

Other separate efforts that apply linked data and ontology to capture some aspects of emergency response are presented in recent researches on various facets. In the context of Weather Ontology, it was discussed in detail about AEMET, the Spanish Public Weather Service in [40] where they use the ontology to make meteorological data publicly available via their website, as registered by its weather stations, radars, lightning detectors and ozone soundings. They also discussed the reusing of Time Ontology and Location Ontology to make it more suitable to cater to the Weather Ontology itself.

I took into consideration the content of the messaging information protocol related to the disaster such as a Common Alerting Protocol (CAP). It is the format of a message for all forms of notifications and alerts in the management of emergency and it is implemented in XML. The schema has the following components:

1. Alert – This is basic information regarding such messages as id, purpose, source, link to other messages, status, etc.
2. Info – This describes the events with respect to urgency, certainty, severity, duration, response methods, links to other useful information
3. Resource – This provides extra information put together in audio files or digital images.
4. Area – This represents geographical locations, which take the forms of postal code, shape (circle, polygon, etc.) and also in the form of longitude, latitude and elevation.

Many reports showed that a lot of people, who needed to be evacuated, had problems finding the nearest evacuation centres that the government and companies had set up for them. As a result, they cannot receive the necessary assistant in a timely fashion. Therefore, the way of providing information about evacuation centres for those people is a very important issue in the future and for research [41]. In this article, they firstly design an Earthquake Evacuation Ontology and secondly, they indicate that computers can be used to inform the most suitable evacuation centres, by using the ontology-based knowledge of earthquake victims' behaviours in real-time.

2.4.4 List of Existing Research Related to Emergency Response

A list of existing research that may be useful for emergency response/earthquake is provided below. It is very important to investigate whether such research can fit into the overall picture. To contribute knowledge in this field, here I list existing research related to ontology.

Table 1: List of Existing Relevant Ontologies to Emergency Response

Item	Ontology	Description	Authors
1	Friend of a Friend (FOAF)	Used to find person, organization and relationship between people	[42]
2	Weather	To "translate" between terms to return all semantically similar data and discover resources without exact keyword match via ontology alignments.	[43]
3	Management of a Crisis (MOAC)	It provides a shared vocabulary for incident reporting as linked open data.	[44]
4	Time	Defines temporal entities such as time intervals, their properties and relationships.	[45]
5	Places	A simple lightweight ontology for describing places of geographic interest.	[46]
6	Geonames	Provides elements of description for geographical features defined in the geonames.org data base	[47]
7	Location	This vocabulary is used to describe the location coordinate of public places	[40]
8	Common Alerting Protocol	A simple but general format for exchanging all-hazard emergency alerts and public warnings over all kinds of networks	[48]

From the best of my knowledge, **Table 1** listed above indicates that there is a lack of ontology studies on concepts for communication and tracking people in the field of emergency response.

In addition, [49] gives principles and guidelines for creating an Open Ontology for Open Sourced Communication System for ER, but it did not coordinate domain experts to create such an ontology.

2.5 Communication Framework

From the previous study by [50], [51], there are four stages that are important in disaster management such as mitigation, preparedness, response, and recovery. Many type of research have used the well-known diagram of the disaster cycle (**Figure 6)** and it is ubiquitously referred to in the literature as illustrated in [52]. Characterising the hazard cycle into these four stages has been created by [53] as in **Figure 6** below:

Figure 6: Emergency Management Diagram Source adapted from [54].

From the **Figure 6** diagram, I developed, improved and enhanced the Emergency Management Plan Framework and focused on communication using mobile apps that are personalised to individual users and is aware of their dynamic situations (in the real time). **Table 2** below shows the description of each phase of Emergency Management Plan diagram as in **Figure 6**:

Table 2: Four Phases of the Emergency Management Plan [55]

The Four Phases of the Emergency Management	
Mitigation Preventing future emergencies or minimizing their effects	• Includes any activities that prevent an emergency, reduce the chance of an emergency happening, or reduce the damaging effects of unavoidable emergencies. • Buying flood and fire insurance for your home is a mitigation activity. • Mitigation activities take place before and after emergencies.
Preparedness Preparing to handle an emergency	• Includes plans or preparations made to save lives and to help response and rescue operations. • Evacuation plans and stocking food and water are both examples of preparedness. • Preparedness activities take place before an emergency occurs.
Response Responding safely to an emergency	• Includes actions taken to save lives and prevent further property damage in an emergency situation. Response is putting your preparedness plans into action. • Seeking shelter from a tornado or turning off gas valves in an earthquake are both response activities. • Response activities take place during an emergency.
Recovery Recovering from an emergency	• Includes actions taken to return to a normal or an even safer situation following an emergency. • Recovery includes getting financial assistance to help pay for the repairs. • Recovery activities take place after an emergency.

Based on key aspects as discussed in [56], the researchers have designed and defined disaster management concepts according to its applicable phase as in **Table 3** below:

Table 3: List of Disaster Management Concepts. Adapted from [56]

Mitigation	Preparedness	Response	Recovery
BuildingCodes	BeforeDisaster	Aid	AfterDisaster

Mitigation	Preparedness	Response	Recovery
DisasterRisk	DecisionMaking	Command	DamageAssessment
HazardAssessment	DisasterFactor	Communication	Demobilization
InformationUpdates	DisasterRisk	Coordination	Effect
LandUsePlan	EarlyWarningSystem	Deployment	EmergencyManagement
Legislation	EmergencyPublic	DuringDisaster	Team
Lifeline	Information	Emergency	LongTermPlan
MitigationGoal	Evacuation	ManagementTeam	Reconstruction
MitigationOrganization	Event	Emergency	RecoveryGoal
MitigationPlan	Finance	OperationCentre	RecoveryOrganization
NaturalSite	Media	EmergencyPlan	RecoveryPlan
NeedsPlan	MutualAidAgreement	Incident	ResettledEvacueesTask
Non-structural Mitigation	Preparedness	Rescue	Resilience
People	Organization	Resource	Resource
Property	PreparednessAction	ResponderTask	TaskReview
RiskAnalysis	Plan	ResponseGoal	
RiskReduction	PreparednessGoal	ResponseOrganization	
StrategicPlanning Commitee	PreparednessTeam	SituationalAwareness	
StructuralMitigation	Pre-Position	SituationAnalysis	
TrainerTask	PublicAwareness		
Vulnerability	PublicEducation		

Table 4 below, I listed all related framework to emergency response and used these as my guideline when I developed my communication and response framework.

Table 4: List of Existing Relevant Frameworks to Emergency Response

Item	Framework	Description	Authors
1	Emergency Management Framework	Provide 4 main components in the framework: 1. Mitigation 2. Preparedness 3. Response 4. Recovery	[50], [51]

Item	Framework	Description	Authors
2	Framework for Emergency DSS	Provide 7 main components in the framework: 1. Input 2. Output 3. Stimuli 4. Directives 5. Interaction Manager 6. Decision Support System 7. Semantic Middleware	[57]
3	Logistic Coordination Framework	Provide 5 main components in the framework: 1. Rescuers 2. Government Body 3. Local Volunteers 4. NGOs 5. Business	[58]
4	Crisis Crowdsourcing Framework	Provide 5 main components in the framework: 1. Types of Tasks (Why) 2. Types of Crowds (Who) 3. Types of Flows (What) 4. Spatial Aspects (Where) 5. Temporal Aspects (When)	[59]
5	RFID Based Secure Mobile Communication Framework	Provide 3 main components in the framework: 1. Organisation 2. Technology 3. NGOs / Community	[60]

2.6 Agent Communication Language (ACL)

To solve difficult problems in a complex system, a single agent's actions are most likely insufficient. Hence, heterogeneous agents of different capabilities are often required to work together, so that they can scale up their efforts to make a true effect in large-scale, distributed complex systems. A system where multiple agents are working together or interacting with each other is referred to as a multi-agent system (MAS). The advantages of MAS including scalability, efficiency, robustness and reusability [61]. However, in order to negotiate, cooperate, collaborate and coordinate between agents, a common communication language is required to achieve interoperability. These interactions can only be carried out if the agents can communicate and understand the communicated message syntactically and semantically. Therefore, I believed the ACL (Agent Communication Language) is one of the important areas in the development of MAS.

The role of communication in MAS is for agents to exchange information based on a set of rules and protocol (communication procedure) of sending and receiving messages. Upon sending and receiving the messages, it must be able to understand the meaning of the messages and must respond accordingly to help produce the best coordination between agents and achieve goals. Additionally, an agent is a software defined by [62] as a software component (e.g. within a multi-agent system) that is capable of exchanging knowledge and information, make autonomous decisions and carry out actions independently.

The Speech Act Theory has been introduced by John Austin and was the pioneer researcher who identified numbers of performative verbs. His research was extended by John Searle who successfully classified the speech act to five classes such as *Representatives*, *Directives*, *Commissives*, *Expressives* and *Declarations* in his book [63]. Based on this theory, two of the most popular Agent Communication Language has been proposed. FIPA (Foundation for Intelligent Physical Agents) that is a non-profit organization and formed by various organizations from academics to industry. It had developed FIPA-ACL. Another ACL named KQML (Knowledge Query and Manipulation Language) was developed by DARPA (Defense Advanced Research Projects Agency). Such formal languages are important for (autonomous) communication systems to ensure that agents understand each other when communicating with one another.

In this study, I used FIPA-ACL (de-facto standard up-to-date) instead of KQML, since KQML has been criticized due to its poor semantics [64]. The FIPA-ACL is the enhancement of KQML and therefore it is chosen in this research. The first FIPA-ACL specification was released in 1997 and revised in 1998. The last updated version of FIPA-ACL is in year the 2002 [65], [66]. The syntax between FIPA-ACL and KQML is similar. Its semantic model was adopted from [67] and [68]. FIPA-ACL has represented communication acts as performative. FIPA-ACL does not limit itself to accept new performatives [64], but to preserve interoperability the performatives must be agreed by all performing communication agents in both syntax and semantics. **Table 5** and **Table 6** below show the original ACL Performatives [69] and their Parameters [70] as used in FIPA-ACL.

Table 5: List of Original ACL Performative [adapted from 69]

Performative	Description
accept-proposal	The action of accepting a previously submitted *proposal* to perform an action.
agree	The action of agreeing to perform a requested *action* made by another agent. The agreeing agent will carry this action out.
cancel	Agent wants to cancel a previous *request (of action).*
cfp	Agent issues a *call for proposals*. It contains the actions to be carried out and any other terms of the agreement.
confirm	The sender confirms to the receiver the truth of the *content*. The sender initially believed that the receiver was unsure about it.
disconfirm	The sender confirms to the receiver the falsity of the *content*.
failure	Tell the other agent that a previously *requested action* failed.
inform	Tell another agent something. The sender must believe in the truth of the *statement*.
inform-if	Used as content of *request* to ask another agent to tell us if a statement is true or false. A statement is issued by the performative *inform*.
inform-ref	Similar to *inform-if*, but used in the content of

Performative	Description
	request to ask for the value of the expression (e.g. how certain one is in their judgements).
not-understood	Sent when the agent did not understand the message.
propagate	Asks another agent, so the agent forwards the same *propagate* message to other agents.
propose	Used as a response to a *cfp (call for proposal)*. Agent proposes a deal. This deal can be understood as a *proposal*.
proxy	The sender wants the receiver to select target agents (denoted by a given description) and to send an embedded message to them.
query-if	The action of asking another agent whether a given proposition (i.e. a *proposal*) is true or not
query-ref	The action of asking another agent for the *object* referred to by (using) *referential expression*.
refuse	The action of refusing to perform a given *action* and explaining the reason for the refusal.
reject-proposal	The action of rejecting a *proposal* to perform some actions during a negotiation.
request	The sender requests the receiver to perform some *actions*. Usually to request the receiver to perform another communicative act.
request-when	The sender wants the receiver to perform some actions, when some given propositions become true (e.g. do when X=true).
request-whenever	The sender wants the receiver to perform some actions, as soon as some propositions become true; but also do it thereafter each time when the propositions become true again (e.g. do whenever X=true).
subscribe	The act of requesting a persistent intention to notify the sender of the *value of a reference* (of an *object*), and to notify again whenever the *object*

Performative	Description
	(identified by the reference) changes.

Table 6: List of Original FIPA-ACL Parameters [70]

Parameter	Category of Parameters
performative	Type of communicative acts
sender	Participant in communication
receiver	Participant in communication
reply-to	Participant in communication
content	Content of message
language	Description of Content
encoding	Description of Content
ontology	Description of Content
protocol	Control of conversation
conversation-id	Control of conversation
reply-with	Control of conversation
in-reply-to	Control of conversation
reply-by	Control of conversation

2.7 Mobile Application System and Technologies Used for Emergency Response

2.7.1 Introduction

Several application systems have been developed in the field of emergency response in web and mobile applications to assist the tasks of tracked missing people in earthquake disaster. Among other systems/applications, the more well-known ones developed for this purpose especially for the large-scale disasters are SEA-EAT blog [6], PeopleFinder [6], Nepal Earthquake Missing People on Facebook [71], Nepal Earthquake Missing People Website [72]. Some of the applications have applied semantic web and linked data technologies to integrate and share information between search agencies, they are also used to assist management’s decision making and for reporting purposes. However, there are still gaps to be filled, especially for the issues of communication and tracking people in need during and after an earthquake, e.g. using a domain-specific ontology for more accurate information sharing or utilising mobile applications for communication. However, most existing applications have been developed for web base usage. This is unpractical; as it is unreasonable to assume that everyone is carrying a laptop in the state of emergency and will have good Internet access during such time. There is also no personalization available for users to regulate how their personal information may be shared and communicated during normal time and in the time of need.

2.7.2 Existing Communication Tools for Earthquake

A comparison of the current mobile apps information and features provided in the apps has been done. This information is important for the research to understand the current state-of-the-art in order to develop a suitable MKA system. **Table 7** shows existing mobile applications where most of these applications were developed to provide information and news about earthquake and tsunami only. These apps broadcast information to all users who are registered with (sound) alerts. These apps do not give suggestions to users about what to do if the users are indeed in disaster areas. However, Earthquake and ManDown applications have provided an emergency toolkit as extra functions such as a flashlight, strobe light, alarm, “I’m safe” message, motionless, Pre-Alarm, Alarm, SOS button, email, text message and phone calls to selected emergency contacts. One issue of all of the above applications is that they depend on the Internet connection to access the information. FireChat and MeshMe applications have provided a single feature which is messaging between users without using the Internet. One of the aims of this research is to fill/narrow the important communication gaps for ER, by providing a combination of useful/relevant features similar to these applications in a single application. Other aims of the proposed system are to take a pro-active role to help rescuers contact and search people/victims that are trapped or lost in a structural manner. **Table 7** gives a summary of current mobile applications.

Table 7: List of Current Mobile Application Features

Item	Mobile Apps	Purpose	Features
1	Earthquakes Tsunami Pro	Provide earthquake information around the globe.	Provide list of earthquakes information, tsunami information, news information, location and sound alerts
2	Earthquake	Provide plan, what to do information and toolkit	1. Flashlight 2. Strobe light 3. Alarm and I'm safe message. 4. Provide earthquake and shelters information nearby users
3	Quake Alerts	Provide earthquake information and news	Provide list of earthquakes information and news
4	Quake Monitor	Provide earthquake information	Provide list of earthquakes information
5	ManDown	Communicate to other people in selected emergency contacts.	1. Provide motionless Pre-Alarm and Alarm 2. SOS button 3. Email 4. Text message 5. Phone call to selected emergency contacts
6	FireChat / MeshMe	Provide communication chat without require cellular network or wireless network.	1. Normal messaging Social network, 2. Free instant messaging (IM)

Item	Mobile Apps	Purpose	Features
7	Guardly	Alerts and connects with organization's security operations instantly.	1. Location detection capabilities 2. Transmitting real-time GNSS location and indoor positioning within buildings (for select enterprise customers) 3. Providing two-way communication with private security, 911 authorities and safety groups
8	LINE Messenger	Communicate with loved ones to see if they were okay.	1. Normal messaging Social network, 2. Free instant messaging (IM) and 3. Calling through various devices
9	Disaster Alert	Provides mobile access to multi-hazard monitoring of and early warning for natural disasters around the globe.	Real-time access to data on active hazards globally

Item	Mobile Apps	Purpose	Features
10	Life360	Has the ability to connect someone who might be trapped and needs help.	1. Let's a family set up a private network 2. With a click of a button, they can let each other know where they are and if they're safe 3. Has a panic alert feature that can activate to immediately contact family members via text, email and a voice call to give current location at the moment you need help
11	SirenGPS	Provide collaborative emergency communication, management and response by connecting everyone in a community to first responders and allowing first responders to communicate with each other, all on a single platform.	1. Allows first responders to determine the precise location of 911 callers 2. Enables real-time, two-way communication in a crisis, even when cell phone service is down 3. Allows credentialed first responders (fire & police) to communicate and share tactical awareness tools when they arrive on a scene

Item	Mobile Apps	Purpose	Features
12	Red Panic Button	User-centered Early Warning and Vulnerability Alert System (EWVAS), it allows one-to-many mode of communication	1. Pushing the Red Panic Button, the app will send GNSS coordinates and a link to Google Maps, by SMS or email, to a previously specified contact list 2. Enable the app to post to you Facebook or Twitter.
13	ICE: In Case of Emergency	Stores important information for first responders and hospital staff to use in case of an emergency including emergency contacts, insurance information, doctor information, medical condition and anything else you would like to provide.	1. The app can still be used even when the phone is locked 2. Includes an optional “if found” message in case you lose your phone

2.7.3 Mobile Smart Phones and Related Sensor Systems

The advanced technological innovation in electronics makes mobile smartphone nowadays more than just a simple communication tool. It becomes a portable electronic device with integrated basic functions, such as listening to music, watching movies, taking photos, etc.

Smartphones typically include various sensors that can be leveraged by their software, such as a magnetometer, proximity sensors, barometer, gyroscope and accelerometer; and sensors that support wireless communications protocols such as Bluetooth, Wi-Fi, and satellite navigation. **Table 8** explains sensors in smartphone devices. It is the intention of this research to select useful sensors to support ER tasks.

Table 8: List of Sensors in Mobile Smartphone [73]

Item	Sensor	Description
1	Gyroscope	An orientation sensor with accurate precision. It simply calculates the angular velocity of the device. The gyroscope in smartphones is used for tracking the rotation of the device e.g. when user play games, they can feel rotation and the axis. The gyroscope calculates data along with accelerometer and sends the data to the game. Popular apps like Google Sky Map, Android Photo Sphere camera, and much more apps use the Gyroscope data for accurate results.
2	Accelerometer	It measures and calculates the device acceleration. It calculates the three-axis orientation of the device and sends the data to the required apps e.g. the user can use portrait or landscape mode. When the user moves the smartphone in portrait and landscape modes, the phone screen automatically adjusts according to the position with the help of accelerometer.
3	Proximity Sensor	When users are on the call and place the phone near to the ear and the light will turn off. A Proximity Sensor in mobile will detect the near object and send the data to the phone. The sensor works by activating a small beam of light which is reflected by the skin and the device turns off the screen display temporarily.
4	Light-Sensor	Light Sensor is used in smartphones for automatic display light adjustment. This sensor calculates the Illuminance of the environment and sends the data to the device. Then the device calculates the required display brightness and applies the effect.

Item	Sensor	Description
5	Barometer	A barometer is a sensor which usually finds in high-end smartphones. A barometer measures the atmospheric pressure and works with GNSS sensor about the device sea level measurements for greater elevation accuracy.
6	Heart Rate Monitor	This sensor measures the heart rate of the user. It measures the heart rate by placing the user's finger on the sensor. It calculates the user pulse by minute wise and displays on the screen.
7	Fingerprint Sensor	This sensor became most common these days, and it is coming equipped even with a low-end smartphone.
8	Pedometer	Pedometer sensor calculates the number of steps taken by the user. But many smartphones using accelerometer data for the Pedometer data, this data is not accurate as the real Pedometer sensor does. Only a few smartphones are equipped with real Pedometer sensor; Google Nexus 5 is one of them.
9	GNSS	Global Navigation Satellite System, a system that can provide autonomous geo-spatial positioning and able to pick-up signal from other system such as GPS and GLONASS usually included in smartphones. This system will connect to the satellite and gives an accurate position result.
10	Touch Screen	The touchscreen of a smartphone is also a kind of sensor which response to human contact. A touchscreen is made of multiple layers of glass and works with the pressure of a finger.
11	Hall Sensor	Such as an old device which used flip covers to switch off the screen when flipping them on, it used this kind of Hall Sensor which can sense the magnets and respond. Even the latest gen phones from Samsung, and Apple comes with Hall Sensors.

Item	Sensor	Description
12	Magnetometer	This sensor gives the direction of the device is facing. The sensor provides a simple orientation to detect Earth's magnetic field and make smartphones always know the North. This sensor influenced to metal objects such as car, wristwatches, keys, etc.
13	Infrared Sensor	This sensor is used in the devices to project the infrared dots and then they are scanned with an Infrared Scanner. This scanner is mostly used to encrypt the device with the face data of any person.
14	Pressure Sensor	This particular sensor is found in a limited number of devices, this is used to actually detect the amount of pressure being put on the device on the sides or on the screen which will act as additional inputs to the software for preset functionality.
15	Temperature Sensor	This particular sensor is rarely found on the devices, this is used in order to detect the internal and external temperature of either the device or the surrounding temperature.
16	Iris Scanner	This scanner uses infrared and a couple of cameras to actually scan the pattern found in the iris of the peoples, this is again in a term used to encrypt the device with the eyes of a particular person.
17	Infrared Remote	This device is used to give the singles to different machines which use infrared remote to receive signals and perform a particular function.
18	Air Humidity Sensor	This particular sensor is used to find the humidity level in the air.
19	Pulse Oximeter	Pulse Oximeter sensor is used to find the amount of oxygen that is found in people’s blood. This sensor will not take any blood sample but will identify the oxygen level by the light.

Item	Sensor	Description
20	Geiger Counter	Geiger Counter is made to detect and measure the number of ionizing radiations in different places. It is found in the really low number of devices but can be really useful if the user lives in places near nuclear reactors.
21	NFC	Near Field Communication sensor is used to validate transfer between two devices. This can easily be used to make financial transactions and can even be used to share photos and videos.
22	Laser	The laser is used in different devices to actually measure the distance between the mobile phone and the thing behind it. It can be used to focus the phone camera more accurately.
23	Air Gesture	Air Gesture has been used in devices such as Samsung Galaxy S4 & Samsung Galaxy S5 where the user can easily put the fingers above the display to actually make some features work.
24	Microphone	A sound sensor that measures and detects the sound loudness. In smartphones technology, it generally used micro-sized electret microphones and functioning during the conversations. It also used for voice search or voice commands for digital assistant apps such as Google Assistant, Siri, etc.

2.7.4 The Principles of Human-Computer Interaction Principles for Mobile Devices

Mobile devices are multi-functional devices capable of hosting a broad range of applications. Like a personal computer operating system (OS), a mobile OS is the software platform that determines the functions and features available on the smartphone, such as a thumbwheel, keyboards, wireless security and synchronization, messaging and etc. Some of the more widely-used and well-known mobile operating systems are Google's Android and Apple's IOS. A comparison of these types of device in terms of their system architecture [74] and security [75] are important to understand the behaviour of the mobile OS before I can decide which platform would be more suitable for my system.

The mobile computing devices of nowadays, including smart watches, mobile phones as well as other small computers (smart devices) have a number of implications for the user interface design. These devices have a problem in common: attempting to grant users access to very powerful computing resources and services through very small interfaces that usually have very small visual displays, limited input techniques and poor facilities for audio interaction. They are also faced with new challenges, among which are supporting irregular and very costly network access, context sensitivity and position awareness.

Designers are no longer making such cell phones with an assumption of a traditional model in which users will be making use of a PC at their place of work. Besides size requirements and mobility, mobile devices are also going to be used by a population which is much larger than the population of PCs' users and there is neither a support network nor technical training, be it informal or formal. What is more, they are different from the oldest computers, which would permit sharing a computer by many users. At present, one user can own several mobile phones which they use in various ways and for various tasks.

The actual effectiveness of a mobile system is achieved when there is an appropriate balance between functionality (i.e. a set of action/services that system offers) and usability (i.e. which system can be used efficiently and properly performing goals for certain users). Mobile devices present human-computer interaction (HCI) designers with 10 principles, each may come with its own challenges, as shown below [76]–[78]:

1. Don't Miniaturise (very small text)
2. Context (event, statement, or idea and in terms of which it can be fully understood and assessed)
3. Integrity Aesthetics (nicely sorted and structured)
4. Consistency (in terms of elements or system flows)
5. Multi-Touch
6. Feedback

7. Metaphors (easy to understand even just use icons)
8. Rapid Selection
9. User Control
10. Minimise the Pain (i.e Allow offline use)

2.7.5 Ad-Hoc Peer to Peer Network Communication Protocol and Strategies

One of the important functions of a smart device is communication. There are two major approaches used in mobile smart devices named satellite communications and mobile network. The technology used in satellite communication involves an artificial satellite that is stationed in space where the communication facilities provided will guarantee high independence. A well-known current mobile network technology is placed into various categories depending on the purpose, range, radio waves limitation and geological features. The categories are: a) Wireless Wide Area Networks (WWAN) incorporates GSM/CDMA/UMTS, which is popularly referred to as 2G. Another technology used is CDMA2000/WCDMA/TD-CDMA, which also called 3G and Long-Term Evolution (LTE) for 4G. In comparison with the 3G service, 4G permits speech and data services to be used simultaneously and is therefore associated with a higher cost of data. b) Wireless Local Area Networks (WLAN). Mobile stations fall under this network and can connect with each other via access points. c) Wireless Personal Area Networks (WPAN) is perfect for short-range connectivity that covers an area of about 10m and the frequency system used requires no license [79].

It is possible for a group of mobile devices with wireless communication capabilities to form a temporary communication network without using any mobile network infrastructures (such as WAN, LAN, 3G, 4G or 5G, etc.). This technology is known as an ad-hoc mobile network where two or more hosts (smart devices) communicate with each other using Bluetooth, Wi-Fi or other appropriate communication mechanisms - as long as they are within the reachable distance of each other, the distance varying with the used communication mechanism. However, they may still communicate with each other even if they exceed this distance boundary, if additional hosts within the communication distance between them are collaborating within the ad-hoc network and have the temperament to forward packets for them.

A common problem in network communication is the nature of how the messages may be transmitted from the *Sender* to the intended *Receiver*. The nature of ad-hoc mobile networks is dynamic in order to cope with a challenging environment, such as the formation of a temporary local connection because of the users' movement from one place to another. The movement of every user may differ. It is even possible for certain hosts to stop communication in order to undertake tasks which are based on locations.

The common method to build an ad-hoc communication network between smart devices is to create paths of intermediate nodes which depend on the transmission range of each device to be able to communicate directly with each other. Pairwise [80], alternatively P2P, communication approach is often found in ad-hoc mobile networks when it uses pairwise communication that covers a very small space (i.e. to the range of transmission) or a dense space (i.e. including thousands of nodes which are wireless). When there are sufficient hosts covering the entire area, broadcasting can be accomplished efficiently.

P2P networks can be very important and useful to resolve an issue when mobile network or satellite communication totally cannot be used. This happened, for example after the earthquake struck Nepal in 2015 [22], the network could not be used because the cell tower was damaged and took time to fix. P2P technology is useful for applications such as telephony, file sharing and other forms of communication. It is not limited to apps but also capable of using extra features (e.g. Bit Torrent **)** that are still in research [81]. Among the common features of P2P systems are: 1) eradication of over-dependence on servers coupled with their inherent issues of scalability, 2) self-organization, 3) ability to adapt to the changing population of peers, 4) heterogeneous peer populations. There exist many designs for P2P overlays in [82] and many commercial deployments that scale to millions of peers which are connected simultaneously [83].

One of the limitations of ad-hoc networks is when it needs to cover a wider area but only a few hosts are available. In this case, hosts that are too far from the intended sender/transmitter (out of communication range) are not able to receive any broadcast message from the *Sender*. Link failures will occur even following the (initial) establishment of a valid path; when some key hosts move outside of the communication range (even just temporarily) they will not be able to forward messages onwards. Also, it is important to consider that the path created in this way is likely to be very long, even if it involves connecting nearby hosts.

In order to offer the best communication in different circumstances where different devices have a different signal-receiving module, 2G and 3G as well as a 4G networks can be considered as a medium suitable for communication in a disaster event. These different mobile network technologies are able to facilitate the high efficiency of data such as uploading the high quality of picture or video. This is very important where on several occasions, the document requires more time to transmit whereas multimedia like video, a record of an image is a better way to report the on-site situation. Time is particularly important in rescue moments [79]. Hence, 2G/3G/4G is going to offer a better platform than P2P for data transmission and communication. However, 2G/3G/4G network will not work if the communication facilities are disrupted, then a combination of P2P and a mesh network becomes a network of choice.

There is an excellent technology known as mesh networks for cell phone that has been made use of in Hong Kong [84], which permits people to communicate with one another and it does not require Wi-Fi nodes or cell towers and enables mobile phones to connect, thereby forming a short-term internet high-performance computers which boost the network. **Figure 7** below shows the concept of mesh networks. Mesh networks have proven to be highly effective and can be promptly used during political unrest or times of disaster, as they do not depend on wireless networks or existing cable [85]. In Iraq, many people have utilized this technology as a follow up to the government limiting connectivity in a bid to disrupt communications by ISIS members [84].

I have used P2P and mesh networks technology in this research. Since I argue it is important that applications can use the internet in emergency response especially in earthquake disaster, I proposed a mobile application with P2P mesh technology environment in order to increase the possibility to track and help people in the earthquake disasters.

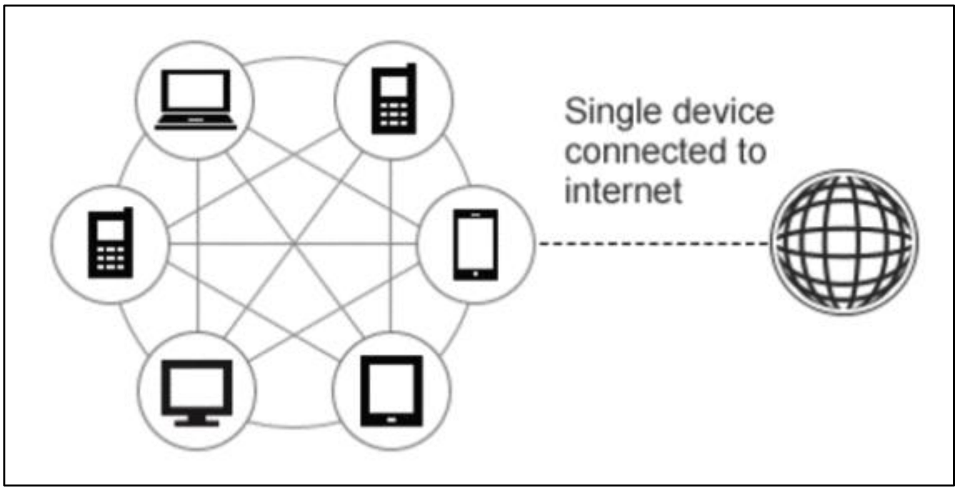


Figure 7: Mesh Network Diagram

2.8 Summary

In summary, in this chapter, I have discussed in detail the impacts of big disasters, including earthquake information, some of the current ER projects conducted by government and research centres, knowledge representation, communication framework, ACL and mobile phone technologies where all of this information is useful to my research.

I believe some of the research is ongoing and also has been done by government and research centres to support victims and rescue organisations during the emergency response situation. Most of the projects and technologies I studied focused on monitoring and coordination between organisations to help victims using high-performance computers that they require the integration of all resources for data analysation purposes.

From the best of my knowledge, I found a lack of research in the field of ER using mobile technologies and the fact that no suitable personalised mobile system is available to help individuals, especially those at risk or members of the public (communities). This would impede effective communication between the first responders (esp. those from the public) and victims during and after the disasters. Therefore, my research is focused on the communication with victims and tracking them while providing live monitoring facilities, Inc. their well-being status, to assist the best rescue strategy to be taken.

Chapter 3 – A Formal Framework for the Personalised Mobile ER-Communication

3.1 Research Methodology

This chapter presents the phases that this research had gone through. It is important to follow a proper and consistent approach when conducting all phases of research [86]. It would also be easier to accomplish research objectives if follows a well-defined methodology structures what have different phrases clearly defined.

In my research, I identified my research methodology as described in **Figure 8** below. I will explain in more detail with regards to MKA System Development and Evaluation phase in **Chapter 4** and **Chapter 5**.

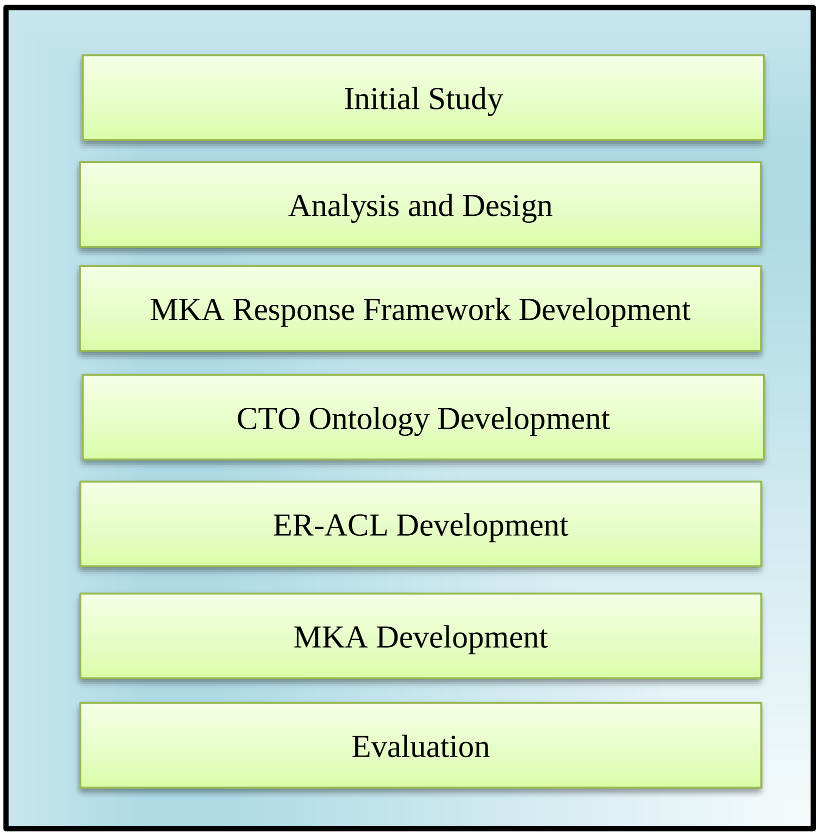


Figure 8: Research Methodology

3.2 Initial Study

This phase occurred at the start of the project. A project topic was found and then discussed. The aim of the research and that of the system were subjected to an analysis and defined depending on the statement of the problem. Moreover, the scope of the research was identified to draw the boundary of the project.

3.3 Analysis and Design

In this phase, I searched for information through literature review from such suitable and available sources, including books, proceedings, journals, papers, reports, journal and news to have the guideline drawn based on related information. I focused on the emergency response, a large scale of disaster as well as mobile smartphone technology studies. This was discussed in **Chapter 2** in the previous chapter.

3.4 Mobile Kit Disaster Assistant (MKA) Communication Framework

3.4.1 Introduction

Improvement of the present emergency management plan framework as indicated in **Figure 6**, **Section 2.5** is meant to be utilized by MKA System to contribute to disaster relief within the shortest time possible. My new ER Communication Framework is going to be utilized for the provision of a foundation for multi-disciplinary skill in a dispersed environment that is multi-agent based, where victims, mobile devices, rescuers as well as other organizations are tailored to function as collaborative and distributed agents to lend a helping hand to each other if there are such disasters as earthquakes.

3.4.2 Mobile Kit Disaster Assistant (MKA) Communication Framework

I adapted the Emergency Management Plan Framework (**Figure 6**) and then I enhanced the *Response* component to develop my framework. From the **Figure 9** diagram, I showed at the left side is an existing framework and how I adapted and enhanced to MKA Communication Framework as on the right side of the diagram. The existing framework was developed for general emergency response plan purposes where it designed to included e.g. buying insurance in mitigation phase, education for evacuation plans in preparedness phase, actions taken to save lives in response phase and getting financial assistance to help pay for buildings/houses repair. However, MKA Communication Framework was enhanced and modified to fulfil and specific to communication in the environment of earthquake disasters where the goals of this framework are to alert and tracking people in needs. This framework has built to meet the mobile application environment and requirement where it contains four elements such as Victim, Family and Friend, Rescuer & Public Volunteer and Medical Rescuer & Public.

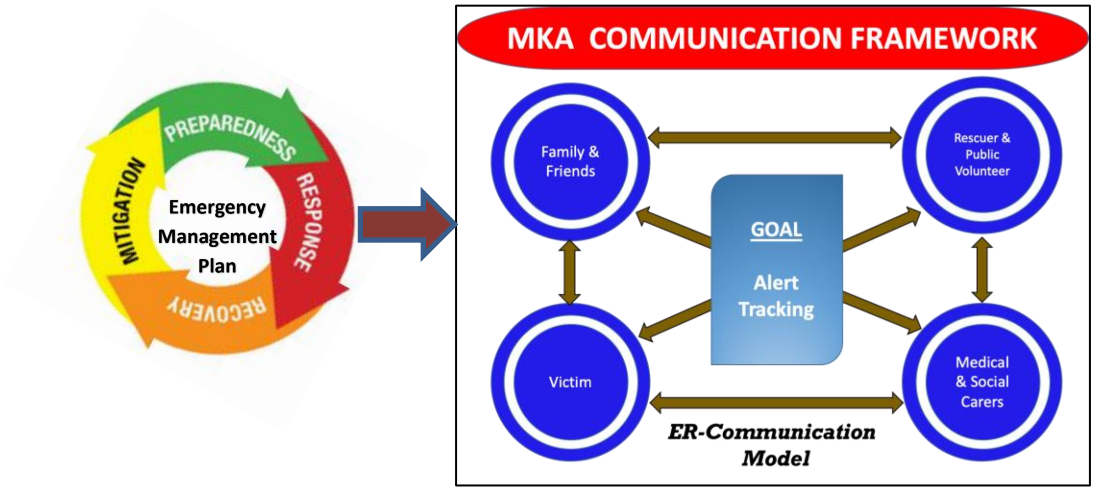


Figure 9: MKA Communication Framework

The goal of MKA Response Framework is to provide a guideline on how current mobile technologies can be used to save a life, by locating, monitoring and rescuing people who are trapped, injured or lost. With mobile and telecommunication technologies, victims can be alerted, tracked and rescued in the real-time by their family and friends, people near-by, communities and rescuer. In this framework, there are four main components involved in a communication cycle during and after an earthquake disaster. The different roles that are being described in this framework are described below:

1. **Victim –** A person or someone that has been trapped, hurt, damaged, killed or has suffered caused by the disaster.

2. **Family & Friend** – A Family is a group of people who are related to each other such as a mother, a father and their children and Friend is a person who close to victim well but who is usually not a member of victim family
3. **Rescuer & Public Volunteer** – Rescuer is a person who helps the victim out of a dangerous, harmful or unpleasant situation and Public Volunteer is a person who does something especially helping other people willingly and without being forced to do it.
4. **Medical & Social Carer -** Medical is a person who related to the treatment of illness and injuries task and Social Carer is a person who care for someone in society who need special help in order to live comfortably.

3.5 Communication and Tracking Ontology (CTO)

3.5.1 CTO Development Method

Tom Gruber defined an ontology as the following *"An ontology is an explicit specification of a conceptualization."* [87]. It is important to understand what ontology is for. The ontology is to enable knowledge sharing and data consistency and as such an ontology is a specification for making ontological commitments.

There is no one "correct" way or methodology for developing ontologies and this research has followed the seven top-level steps from [88] (see **Figure 10**) where the main components are described below.

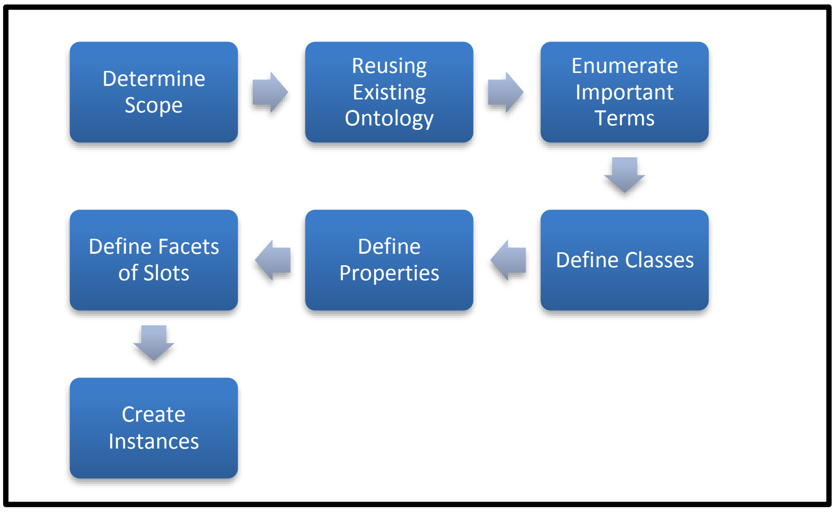


Figure 10: Seven Steps to Develop Ontology

3.5.1.1 Determine Domain and Scope

Naturally, the concepts describing communication and tracking during a large-scale disaster, type of disaster, weather, places, shelter, whom to contact and etc. will figure into Communication and Tracking Ontology (CTO). At the same time, it is unlikely that the ontology will include concepts for victims, rescuer, community and families to trace and connecting each other. The ontology designed and focused to make people's traceable during the earthquake disaster, able to safe and secure after the disaster such as how community or agencies can help peoples nearby (walking distance). Victims who trapped or need help can send a help message to volunteer to inform that they are still alive. Probably, the victim also can find the nearest shelter from their current location to get food, water or blanket supplied.

3.5.1.2 Reusing, Merging and Tailoring Existing Ontologies

Some of the ontologies are available in electronic forms and can be imported into a development environment. This approach is called reuse process where possibly a cost-effective way to build ontologies. CTO was built by means of reuse, following an evolving prototyping life cycle. From 11 main component in CTO, several of them were reused from existing stable and maintained ontologies such as Friend of a Friend (FOAF) [42], [46], [89]–[91], whether [43], [46], [92], Disaster [44], [46], Time [40], [45], Places [40], [90] and Location [40] ontology. All components have been selected and focused on the field of communication and tracking area.

3.5.1.3 Enumeration of Important Terms

In this phase, I list all of the terms that are related to my ontology. They are listed in **Table 9** below:

Table 9: List of Terms used in CTO

Terms		
Accommodation	Gender	Police
Agencies	Green	Police station
Agency building	Help worker	Postal
Agent	Hill	Pressure

Terms		
Apartment	Hospital	Race
Available capacity	Hostel	Radiation
Blood type	Hotel	Red
Chemical emergency	Houses	Red Cross
Church	Humidity	Religion Places
City	Island	Riverine flood
Cliff	Landed house	School
Colleague	Landslide	Service apartment
Commercial resources	Latitude	Severity status
Contact Details	Location	Shelter
Coordinate	Longitude	Shop
Country/Region	Medical staffs	Shopping mall
Dam failure Date	Military	Start
Date of Birth	Mosque	State
Disaster	Mothers name	Support Group
Duration	Mount	Support group
Earthquake	Neighbors	Surname
End	Network available	Temperature
Event	Network Connectivity	Temple
Explosion	Network down	Terrain
Family	Next of kin	Time
Fault	NGO	Total capacity
Fire	Nickname	Tsunami
Fire station	Nuclear power	Valley
Firefighter	Other building	Weather
First name	Other individual	Wind
Flash flood	Others	Yellow
Flat	Peninsula	
Flood	Person	
Friends	Places	

Sources from [10], [11], [41]–[43], [45], [46], [79], [90], [93]–[95].

3.5.1.4 Define the Class Hierarchy

This research has decided to focus on earthquake events because an earthquake can occur without any advanced warning that makes the mitigation of the disaster difficult. Unfortunately, earthquake events can be frequent and their impacts may be devasting in terms of economy and human lives. On the other hand, for other natural disasters, there are prediction systems that can be used to help people to better mitigate the event. As a result, I have chosen an earthquake as a case study. As MKA system is a knowledge-based system that is domain dependent, I have created an ontology in the domain area of earthquake. However, as my developed framework and agent communication language and the corresponding protocol are generic and domain-independent, they can therefore be used in other domains by instantiating a different domain ontology. In fact, this system can be used for small-scale and individual emergency response when adapted suitably.

There are several possible approaches in developing a class hierarchy as mention in [96] but in my research, I used a combination of the top-down and bottom-up approached in the development process. Once some of the classes defined, it must describe the internal structure of concepts. The main classes in the present CTO are Agent, Communication Mechanism, Data Type, Earthquake Early Warning System, ER-Agent Communication Language, Facility, Location, Role, Time, Time Zone and Wireless Communication. **Figure 11** below shows the classes and hierarchy for CTO.

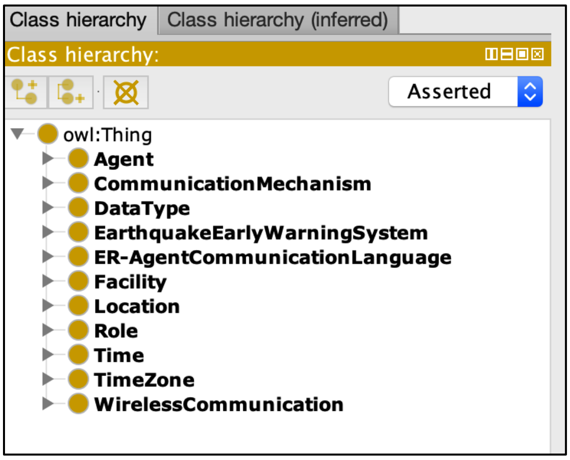


Figure 11: Main Classes and Hierarchy in CTO

3.5.1.5 *Define Properties*

For each property in the list, it will determine which classes will be described. The classes alone will not provide enough information to answer the competency questions. Once some of the classes defined, it must describe the internal structure of concepts. **Figure 12** shown the list of property defined.

Figure 12: List of Property Defined in CTO

3.5.1.6 *Define the Facets of the Slots*

Slots can have different facets describing the value type, allowed values, the number of the cardinality values, and other features of the values. For example, the value of a name slot (as in "the name of shelter") is one string. That is, a name is a slot with value type String. A value-type facet describes what types of values can fill in the slot. Here is a list of the more common value types in this article:

- String: Is the simplest value type which is used for slots such as name: the value is a simple string
- Number: Value types of float and integer are used.
- Boolean: Yes–No flags.
- Enumerated: List of specific allowed values for the slot.
- Instance-type: Relationships between individuals.

3.5.1.7 Create Instances

The final step in ontology development is creating individual instances for classes in the hierarchy. The CTO example can create an individual instance St Peters Scottish Episcopal Church to represent a specific type of Places. The value of 1,000 is an instance of the class Total-Capacity representing Shelters. This instance can be defined using the following slots.

- Total Capacity: 1,000
- Places: St Peters Scottish Episcopal Church
- Location: City of Edinburgh
- Coordinate: Latitude: 55.9340072, Longitude: -3.1826143
- Event: Earthquake

3.5.2 ER-Communication and Tracking Ontology (ER-CTO)

Ontology Web Language (OWL) is a standard and broadly accepted semantic web ontology language [97]. It's used to describe knowledge and can be used by applications to process the content of the information. OWL is sufficiently rich to be used in practice to interpret content and supported by XML, RDF and RDF Schema [98].

Ontologies have become core components of many large applications. Previous research shows a few ontologies for disaster management, emergency response and others have been done. For examples, AEMET Weather, Disaster Management, Management of a Crisis (MOAC), FOAF, etc (described **Table 1** in **Section 2.4.4)** was developed and used in web application system to coordinate between agencies and for reporting purposes.

My research reused and extended existing ontologies created by other researches, where appropriate, to address communication issues of the MKA System. To make CTO suitable for ER application especially in a mobile device, I carried out evaluations with domain experts to create a new CTO ontology.

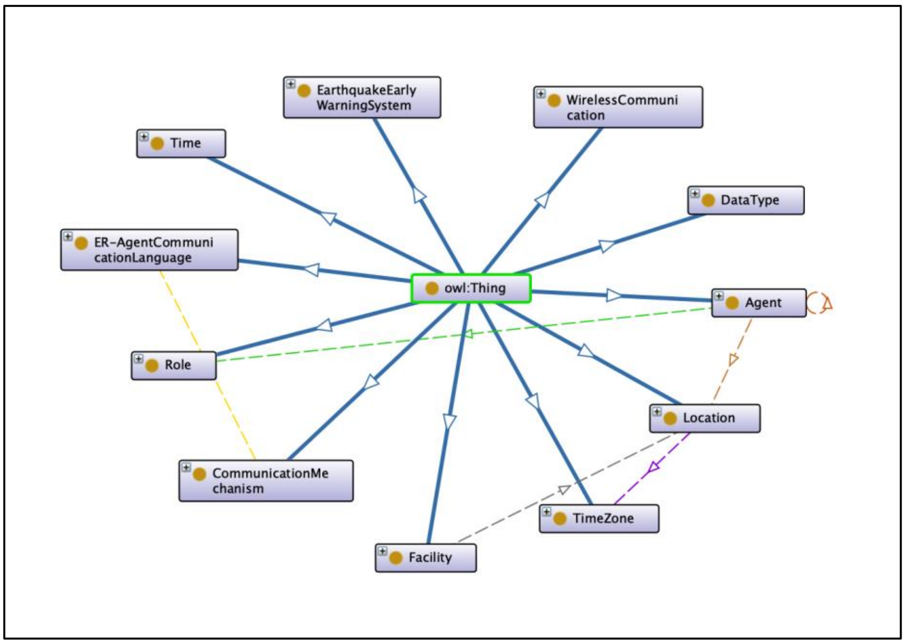


Figure 13: Details of Communication and Tracking Ontology

Figure 13 gives an overview of the CTO I developed by following the seven ontology building steps as mention in **Section 3.5.1** and had developed it using Protégé v5.1.0. CTO includes 11 top-level classes to describe the communication and tracking issues during an earthquake disaster and corresponding emergency response tasks. The main classes and their function are described below:

3.5.2.1 Agent

The most important class in CTO is an Agent Class which contains two subclasses called *Person* and *Organisation*. These classes aim to spread personal information to potential rescuers and also information about organisations to those who need help. The personal information can give a better idea to community or help workers to get necessary background information during and before the rescue process such as personal profile. Subclasses of the class "organisation" are organisations that typically help in an ER situation, Inc. *Emergency Response Team*, *Police, Fire Fighter*, *NGO*, *Military* and *Medical* Organisation. See Agent Class in **Figure 14** below.

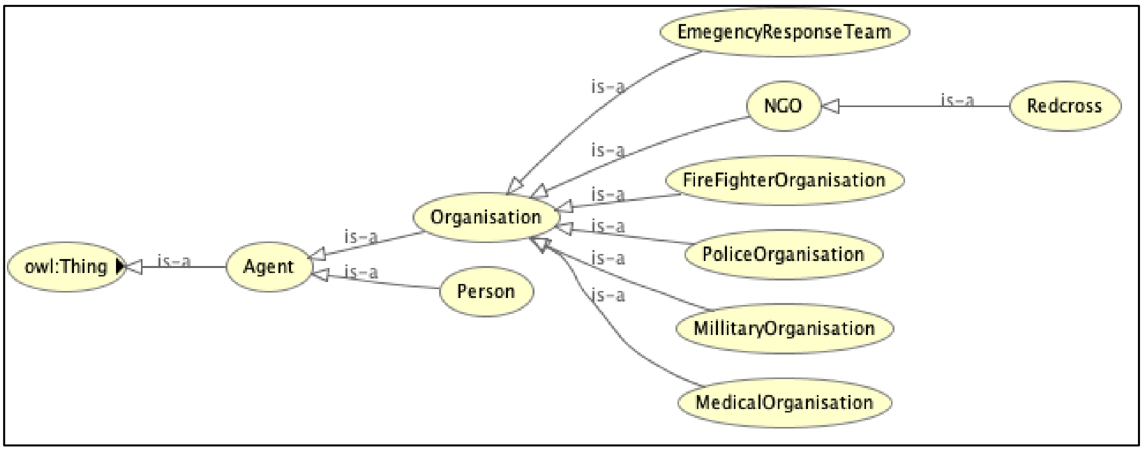


Figure 14: The Branch of Agent in CTO

3.5.2.2 Facility

Facility stores information about buildings and places which may be used as shelters for victims and survivors. These classes are related to classes of *Location Coordinate* in the ER-Agent Communication Language Class (see **Figure 23**). Facility class contains 5 subclasses in layer 2 and 15 subclasses in layer 3. Layer 2 classes are *Private Housing, Public and Commercial Facility*, *Agency Building*, *Religious Place* and *Other Space*. Layer 3 contains *Temple, Church, Mosque, Police Station, Hospital, Fire Station, School, Shopping Facility, Commercial Accommodation, Stadium/Gym, Apartment and Flat, House, Assembly Area, Carpark* and *Open Space*. These classes are shown in **Figure 15**.

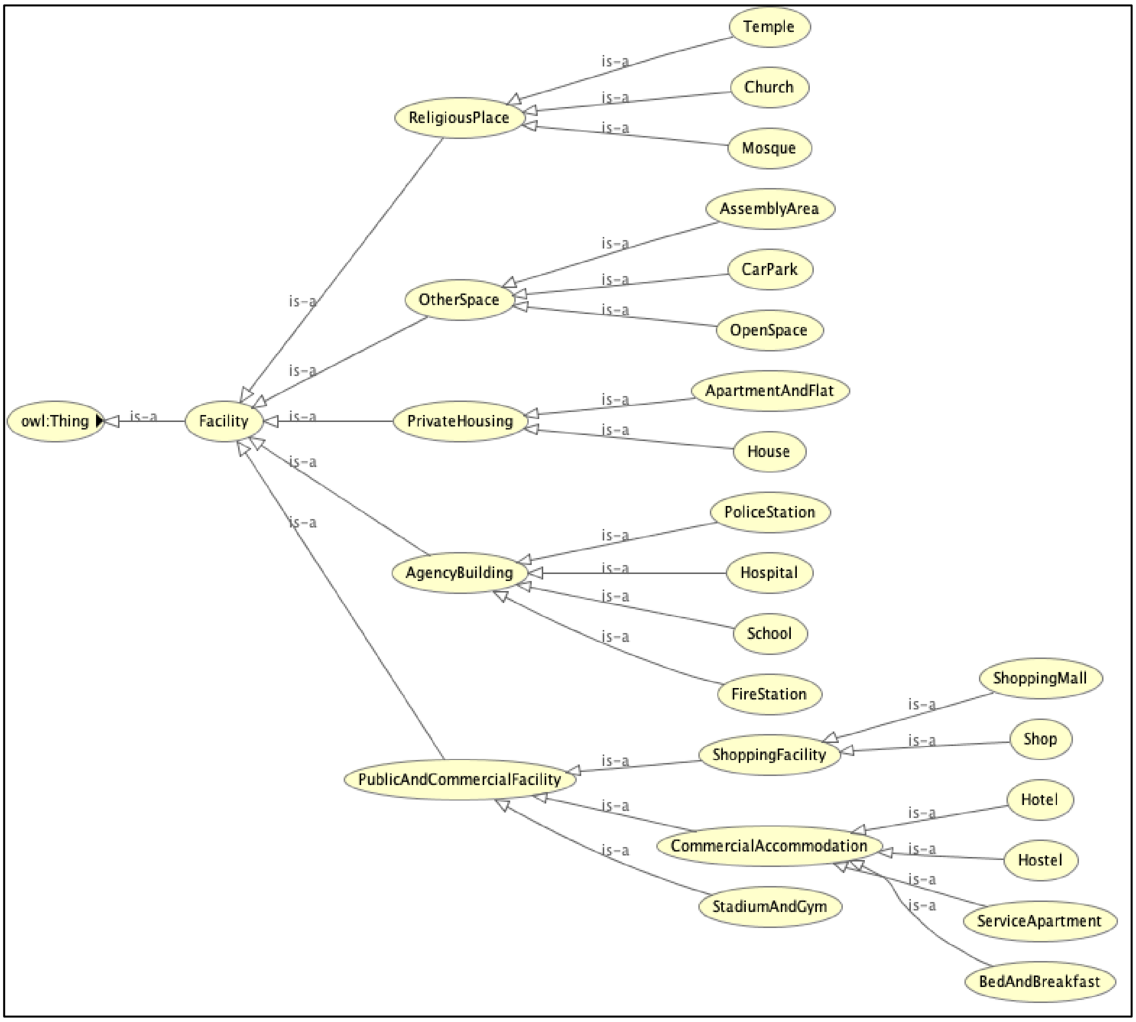


Figure 15: Branch of Facilities in CTO

3.5.2.3 Earthquake Early Warnings System Ontology

The Earthquake Early Warning System (EEWS) class is useful for any ER systems that wish to connect to them. Systems included in this class typically provide EEWS information, such as magnitude, longitude and latitude of the earthquake zone and time the disaster struck the location [99]. There are many EEWS developed and used in a different country. Example systems that are under testing and on-going development are *Elarms* [25], [99], *ShakeAlert* [24], *PRESTo* [100], *UrEDAS* [101], *EDA-MAS* [101], *Earthworm* and etc. The EEWS are listed as in EEWS Class in **Figure 16** below.

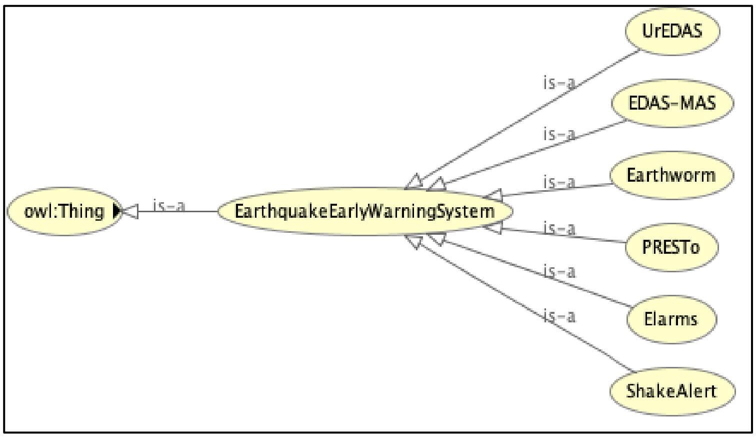


Figure 16: Branch of EEWS in CTO

3.5.2.4 Location Ontology

The class of Location was designed to indicate the information of absolute location so can be used to carry out systematic pairing using GNSS. In this research, ESPG: 4326 coordinate system has been used because it is used worldwide especially in GNSS systems. This location information may be expressed as *Region, Street, City, State, Country, Address* and *Postal Code* information. Furthermore, this class linked to *Location Coordinate* (Latitude and Longitude) in ER-Agent Communication Language Class (see **Figure 23**). **Figure 17** shown the Location Class in CTO.

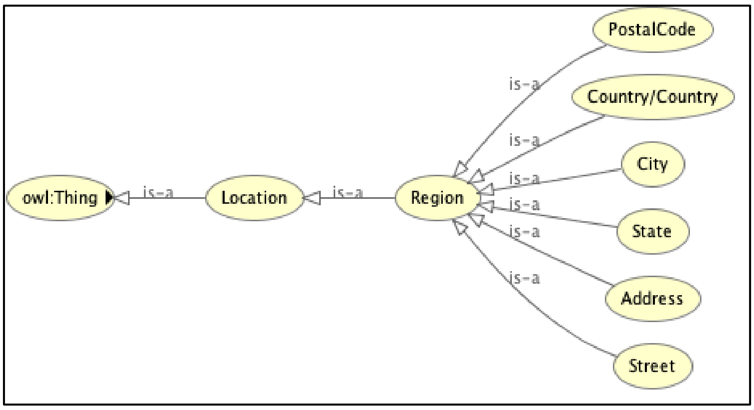


Figure 17: Branch of Location in CTO

3.5.2.5 Time Ontology

Figure 18 shows the Time class that contains the information about the *Date, Time Duration* and *Time Point* (Begin and End Time Point). This class defines time information from the system during the disaster and may help the victims to find the nearest temporary shelters – i.e. temporary shelters will have the beginning and end time availabilities, especially during a large-scale disaster.

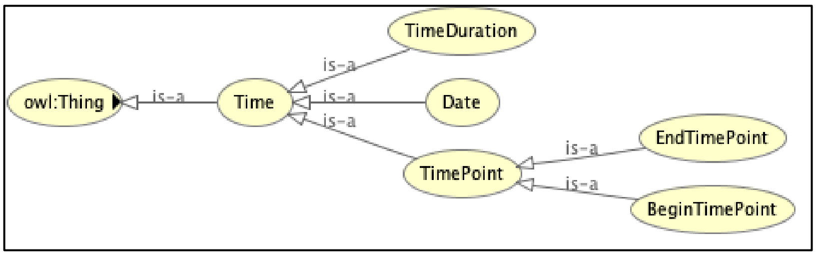


Figure 18: Branch of Time in CTO

3.5.2.6 Time Zone Ontology

Time Zone can be a region of the globe that would have a standard time representation for legal, commercial, and social purposes. This class allows the specification of time zones to allow governments or non-government organisations to more accurately disseminate information around the globe. This class enables the system to collaborate and operate around the clock and deal with different time zones [102], [103]. The class is shown in **Figure 19** below.

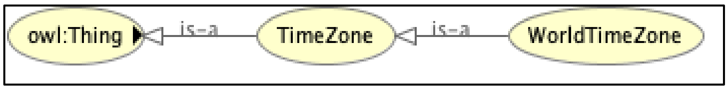


Figure 19: Branch of Time Zone in CTO

3.5.2.7 Role Ontology

The role class in the domain of personalised emergency response and rescue is very important. Different organisations may deal with emergencies very differently, it depends on the impact and standard of procedure in that particular organisation. For example, the Offshore Health and Safety Emergency Team work procedure [104] is very different from the Chemical Industry procedure [2]. I developed my own class in the CTO ontology which is based on the user system's characteristics and personal behaviours and which social positions that the user occupies within a stable social system [105]. My role class groups relevant information of whom may support the victim after a disaster. This Role class is provided in **Figure 20**.

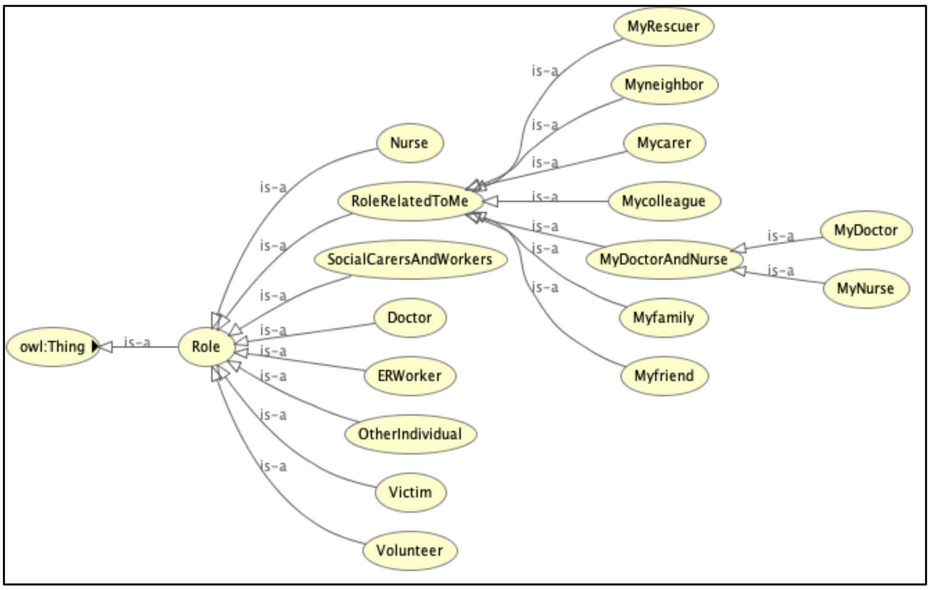


Figure 20: Branch of Role in CTO

3.5.2.8 Data Type Ontology

Figure 21 shows the Data Type class for CTO. This class is built to define data-type information, such as *Distance, Network Connectivity, User Profile, Richter Scale* and *Shelter Capacity* to the system. This class was linked to other classes such as the Agent class.

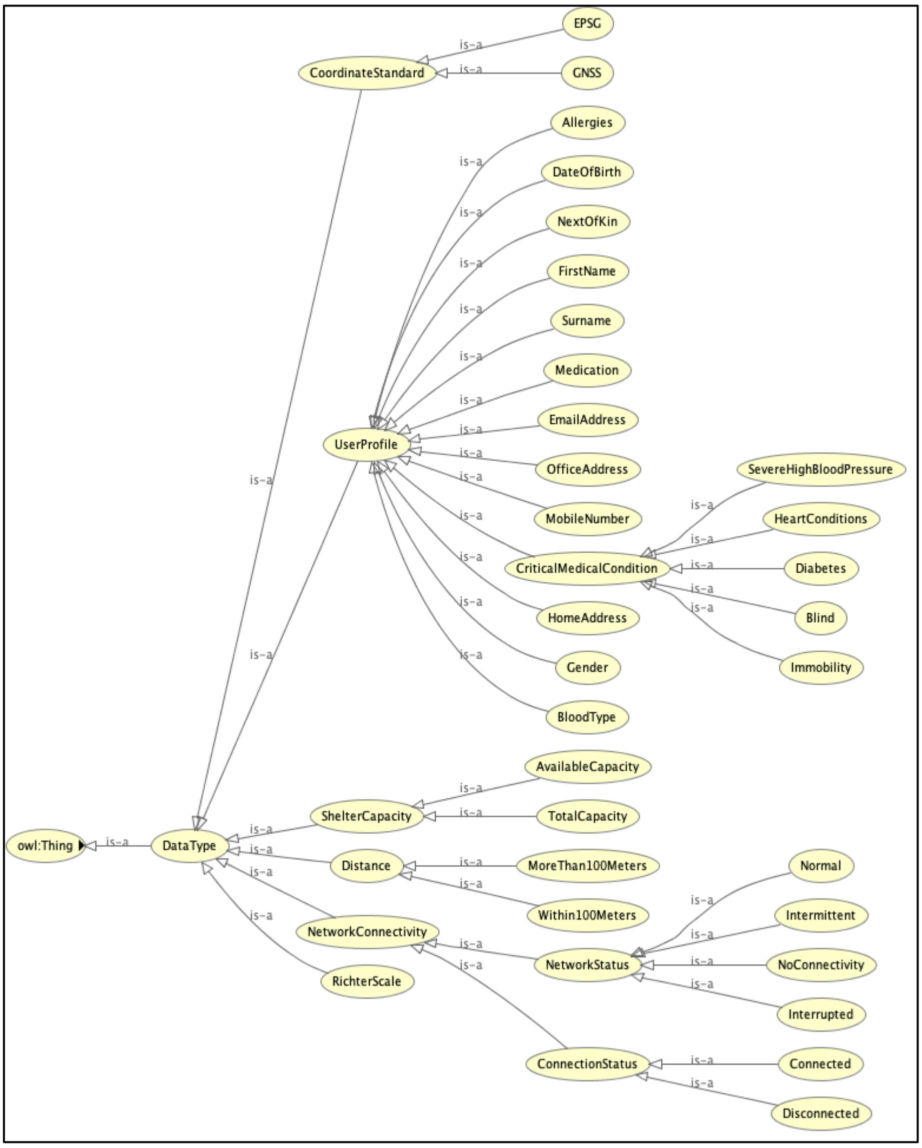


Figure 21: Branch of Data Type in CTO

3.5.2.9 Communication Mechanism

This class describes communication means, such as *Alarm and Alert, Sensory Feedback from Mobile Devices, Gesture from Mobile Device, Voice Message, Image Message, Text Message and Video Message*. **Figure 22** below shows the branch of communication mechanism.

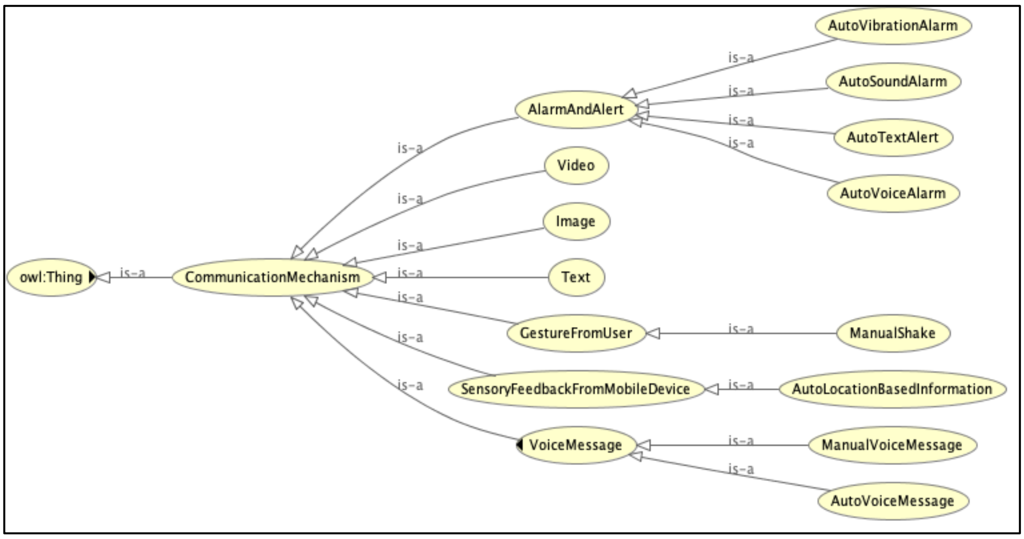


Figure 22: Branch of Communication Mechanism in CTO

3.5.2.10 ER- Agent Communication Language

To enable each agent systems to *'speak'* and understand the *'language'* used between them, a shared agent communication language (ACL) must be used. In this research, I used the ACL as proposed by FIPA as a starting point. I enhance the standard FIPA-ACL to become my ER-ACL to meet my particular requirements. **Figure 23** shows the class ER-ACL which contains *performatives* and *parameters* as used in my system. It is important to have a common communication language, but also a common ontology to promote a more accurate understanding.

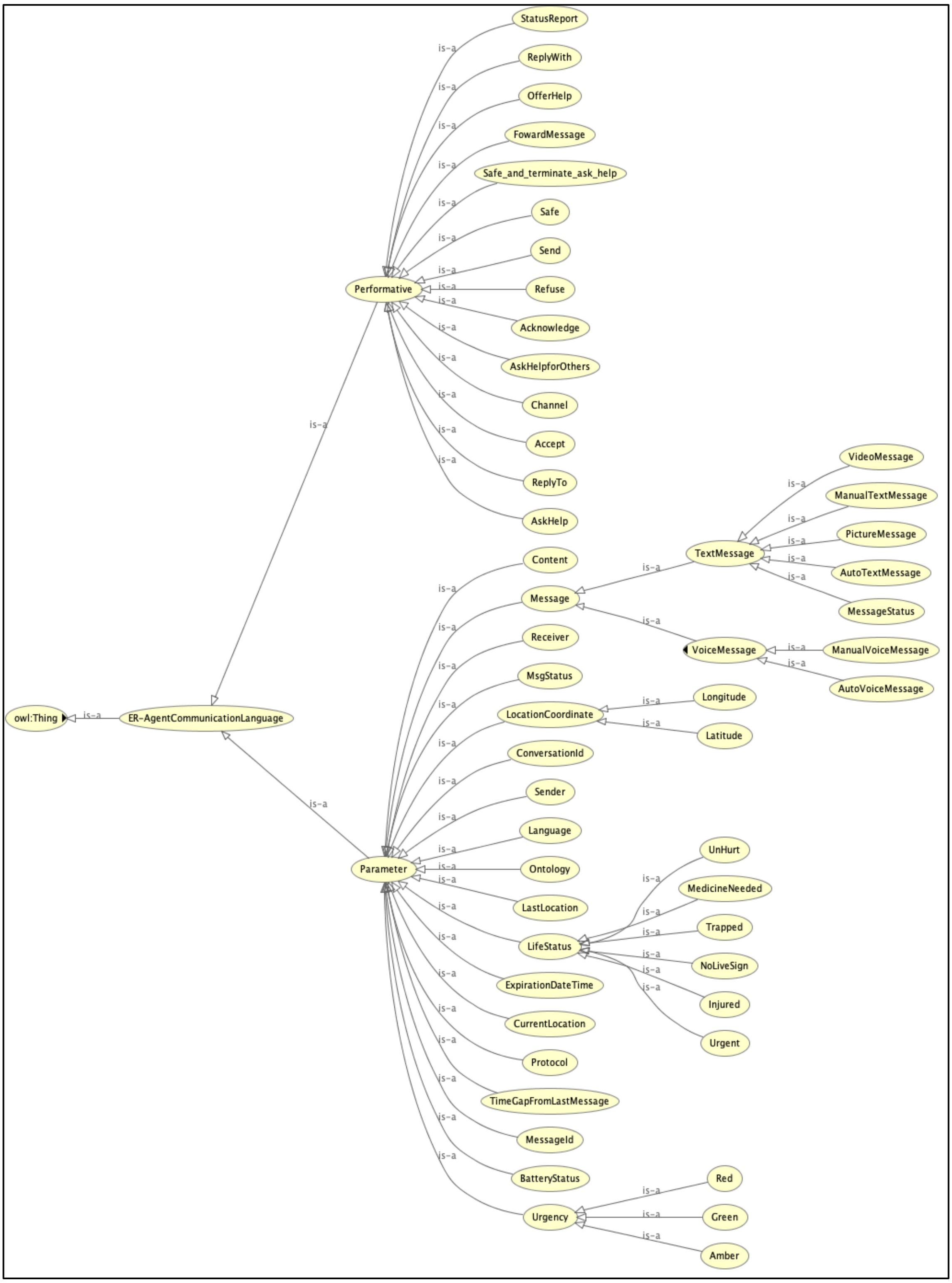


Figure 23: Branch of ER-Agent Communication Language in CTO

3.5.2.11 Wireless Communication

Wireless communication is a class that lists possible wireless telecommunication facilities that can be used in a mobile smart system. The wireless communication is a transferring information method between two or more devices. The common wireless technologies in smart devices are *WiFi, Infra-Red, 3G-Mobile Cellular Network, Bluetooth, Radio and LTE-Mobile Cellular Network* signal [106]. **Figure 24** shows the wireless communication technology class in CTO.

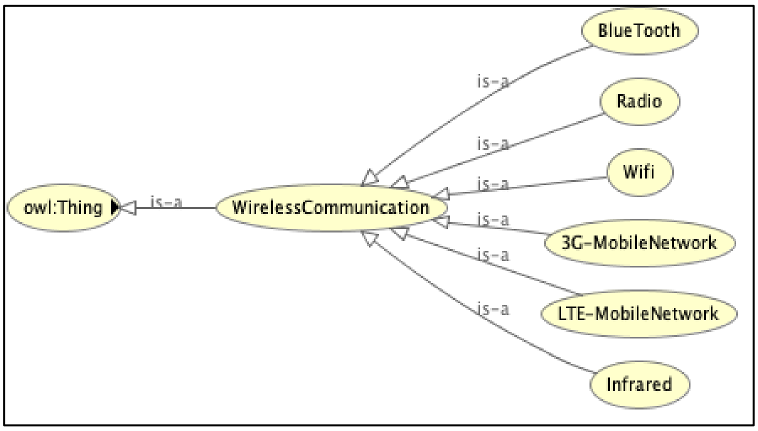


Figure 24: Branch of Wireless Communication Technology in CTO

3.6 Emergency Response-Agent Communication Languages and Protocol (ER-ACL and ER-ACP)

3.6.1 Introduction

To develop a new ER-ACL that is suitable to support the aforementioned research goals, existing ACLs were studied, Inc. FIPA-ACL and KQML, where FIPA-ACL was choosing as main resources and was discussed in **Section 2.6**. Three main documents have been used as main references to develop my ER-ACL and their protocols ER-ACP; the FIPA ACL [70], [107], [108], KQML and Common Alerting Protocol [48], [57], [109]. These documents provide fundament concepts and structure. Here I present the ER-ACL and the part of FIPA ACL performatives that would normally use in emergency scenarios. I will explain the modification and extending of ACLs to ER-ACL as in **Figure 25**.

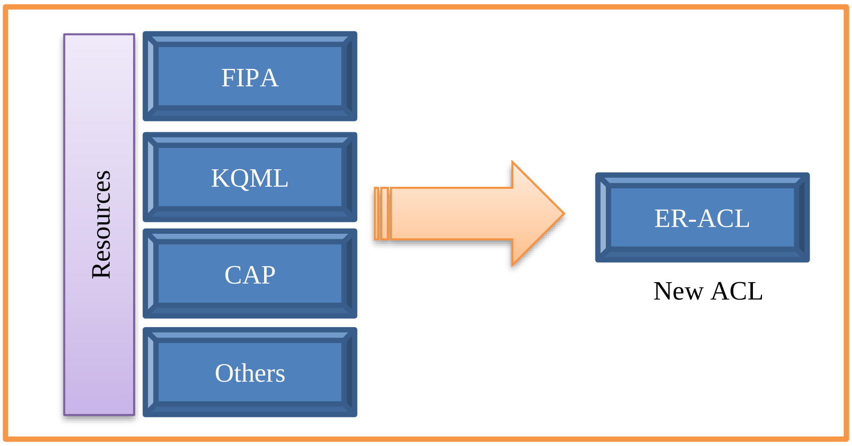


Figure 25: Development process of ER-ACL

ACL can be described as a high-level abstraction method to exchanged information and knowledge between two or more agents. KQML and FIPA-ACL have three layers of organisation structure that contains content, communication and message layer. Content layer represent the message content, communication layer represents transporter such as sender and receiver and message layer encode and wrapping all together including content and communication layer. (see **Figure 26**)

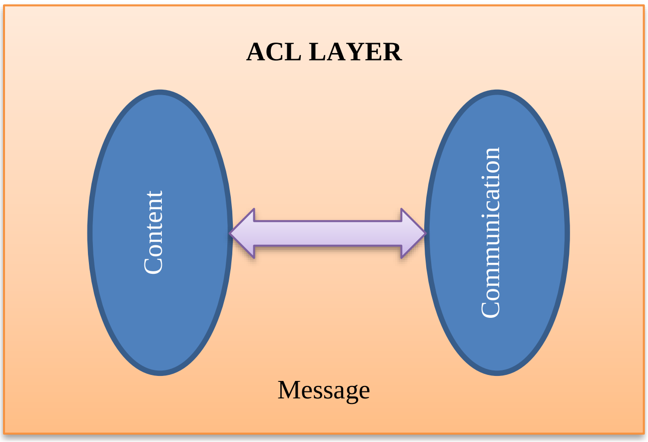


Figure 26: Layers Contain in ACL

3.6.2 *The Emergency Response – Agent Communication Language and its Theoretical Background*

3.6.2.1 Background

To achieve semantic interoperability, different semantic models were developed for ACLs. Three primary semantic models have been identified as *Mentalistic, Conversation Policy* and *Social Approaches*. Based on this approach, the content of a transmitted message between agents can be understood throughout semantic interoperability.

A Mentalistic approach is defined in terms of mental states of an agent such as beliefs, desires and intentions (BDI). In the same way, conversation policy expresses through the composition of speech act in terms of interaction protocol [110] and equally important is a social approach where it defines ACL in terms of commitments as normative agent society.

Two dominant ACLs such as KQML and FIPA-ACL were developed based on the mentalistic approach in which FIPA-ACL used the semantic model as discussed in [67]. Many researches have studied the mentalistic approach which is based on the notion of BDI. For example, research in [111][112] was presented in a rational agent based on the formal theory of interaction named Rational Agent Based on Theory of Interaction implemented by a Syntactical Inference Engine (ARTIMIS). In this method, agents were modelled as the kernel of a cooperative spoken dialogue system that the semantic of communication modelled in first-order modal logic. My ER-ACL followed the design principles of FIPA-ACT and (therefore also) follows this theory.

3.6.2.2 ER-ACL Development

In order to assist effective communication, standardized or common communication languages are needed. As this problem can be suitably framed as an agent-based problem, Agent Communication Languages (ACL) would be most appropriate to be used for the system. A natural approach to communicate between the agents (implemented as mobile applications) is to embed personal information and contextual or situation information in the ER-ACL. I therefore have chosen to extend the existing standard FIPA ACL model for communication between agents and use a suitable ontology to provide the conceptual backbone for the ER-ACL to allow a flexible mixing and reuse of (standard/existing/extended) important information in the mobile application. This allows different information sources created by different people in different places to be interlinked and used together in meaningful ways.

One of the motivations behind the development of FIPA-ACL was the need to address the challenges faced by the Knowledge Query and Manipulation Language (KQML). However, in this research, I found that significant gaps still exist in FIPA-ACL when I tried to apply it to support emergency response scenarios e.g., identification of support network, including rescue workers, ad-hoc volunteers and friends and families, etc. It also does not support multi-gestures, commonly available and used by mobile device users. The other problem is that it does not support functions of different transmission models, e.g. transmission to a particular receiver, or a specific group of receivers or just to the public (unspecified receivers). It also does not have explicit control for communication, e.g. looped communication or handling run-away messages (lost messages). When developing the ER-ACL and ER-ACP, several issues have been considered to ensure the language is appropriate and usable. The following were considered.

3.6.2.2.1 Design Philosophy ER-Agent Communication Language

Similar to [109], important considerations for designing the ER-ACL are:

- **Interoperability** – ER-ACL should provide a well-defined structure and semantics so that messages can be understood correctly in different systems;
- **Completeness** – The ER-ACL should support all of the possible communication information and methods, e.g. (typical) communicated information and its formats, e.g. voice, images and video messages and an indication of their retrieval method.
- **Simple implementation** – The ACL should be as simple as possible to use and implement.
- **Flexibilities** –The constructs should remain sufficiently abstract, while being rich, to be adaptable and extendable to other coding schemes.

- **Multi-use format** – the same message format may be used by different message types issued by different user groups.
- **Familiarity** – The data elements and code values should be meaningful to originators and non-expert recipients alike.
- **Interdisciplinary and international utility** – The design should allow a broad range of applications in public safety and emergency management and allied applications and should be applicable worldwide.

3.6.2.2.2 Design Requirement for the ER-Agent Communication Language

The fundamental requirements for the ER-Agent Communication Language have been listed below:

- Provide a specification for a simple, extensible format for digital representation of warning messages and notifications;
- Enable integration of diverse sensor, Inc. multi-gesture signals on mobile phones;
- Support multiple transmission systems, including WiFi Direct Peer to Peer (P2P), this is needed, as standard telecommunication networks are often down or congested that alternative communication channels are much needed;
- Provide a unique identifier (e.g., Message ID) for each warning message and for each message originator;
- Support suitable pre-defined content, such as:
  - Geographic location
  - Level of urgency
  - Level of certainty
  - Level of threat severity
- Provide multiple message types, such as:
  - Ask-Help
  - Acknowledgements
  - Accept and Refuse
  - Reports of results from information dissemination

- Provide a mechanism for referencing supplemental information (e.g., digital audio or image files, additional text);
- Use an established open-standard data representation;
- Be based on a program of real-world cross-platform testing and evaluation;
- Provide a clear basis for certification and further protocol evaluation and improvement; and
- Provide a clear logical structure that is relevant and clearly applicable to the needs of emergency response and public safety users.

To address these problems, I have extended the standard agent communication, FIPA, to ER-ACL. The newly devised extended performatives are provided in **Table 10** and **Table 11**.

Table 10: List of Performative (Bold are new Performatives in ER-ACL)

Performative	Description	Status
Ask-help	Use for the sender (victim) to a send help message to the receiver (volunteer)	New
Ask-help-forward	Use for the sender (volunteer/family) to forward help message to the receiver (another volunteer)	New
Offer-help	Use for the sender (helper) to send an offer help message to the receiver (victim)	New
Accept	Use to accept a message and replying current situation of sender agent	New
Acknowledge	Use to acknowledge message received from sender	New
Send	Use to send normal messaging between agent	New
Reply-to	Use to reply normal messaging between agent	New
Reply-with	Use to reply-with normal messaging between agent	New
Status-report	Use to send report status to message between agent	New
Channel	The connection method used for data transferring	New
refuse	The action of refusing to perform a given action and explaining the reason for the refusal.	Existing

Table 11: List of Parameters (Bold are new Parameters in ER-ACL)

Parameter	Description	Status
Msg-Id	A communication ID for every message sending	New
Time-stamp	Date and time recorded for every message sending	New
Myrole	Role recorded either victim, volunteer or family	New
Text-message	Custom free text message for communication	New
Life-status	Pre-set message for communication	New
Urgency	Using colour code marker on the map (red, green or amber). Easier to trace people in need.	New
Picture-message	Picture message for communication	New
Video-message	Video message for communication	New
Voice-message	Voice message for communication	New
Last-location	Last coordinate and address for communication	New
Current-location	Current coordinate and address for communication	New
Battery-status	Percentage of battery status indicator from the sender.	New
Message-status	Message status recorded for every messaging sending. How many times the system keeps sending, failed or succeeded.	New
Time-gap-from-last-message	Duration between messages. Helpers may assume life status from the last message	New
Expiration-Date-Time	When network not available, all messages in a queue will be terminated. This will reduce network congestion when network available.	New
sender	Participant in communication	Existing
receiver	Participant in communication	Existing
content	Wrapping and ready to send all type of messages such as text, photo or life status	Existing
ontology	Knowledgebase of the system	Existing
protocol	Performative used in the communication	Existing
conversation-id	Control of version message conversation	Existing

Although the existing FIPA-ACL already consist of reject-proposal, request, request-when and request-whenever performatives, it is very different from my performatives in ER-ACL. These differences may arise from the fundamental differences of their goals. FIPA ACL supports (contract) negotiations and ER-ACL support search and rescue missions. The differences of those performatives are shown in **Table 12** below:

Table 12: Performative Differences Between FIPA-ACL and ER-ACL

FIPA-ACL	ER-ACL
Reject-proposal The action of rejecting a proposal to perform some action during a negotiation.	**Refuse** The action of refusing to perform a given action and explaining the reason for the refusal.
Request The sender requests the receiver to perform some action.	**Ask-Help** The action of sending information for getting help from the victim (sender agent) to volunteer (receiver agent) or by a family/friend (sender agent) to volunteer (receiver agent). There is no action perform needed by the receiver.
Request-when The sender needs a receiver to perform some action when some proposition given becomes true.	
Request-whenever The sender needs a receiver to perform some action as soon as some proposition becomes true and thereafter each time the proposition becomes true again.	
Inform The sender informs the receiver that a given proposition is true.	

3.6.3 The Emergency Response Agent Communication Protocol (ER-ACP)

To explain how the ER-ACL may be used in the Emergency Response Agent Communication Protocol, several communication scenarios have been illustrated in

Section 3.6.3.1, Section 3.6.3.2, Section 3.6.3.3 and **Section 3.6.3.4**. This type of communication may exist among agents such as victim, family/friend and volunteer. In every scenario, I illustrate the ER-ACP protocol that has been implemented in my system.

3.6.3.1 Ask-Help and Offer-Help Communication Protocol

In my study, there are several common EM scenarios that can take place during and after a disaster. For instance, during a disaster, in the first instance, the victims would call for help. This is demonstrated in the Ask-Help and Offer-Help scenario. **Figure 27** illustrates the communication between a victim and a volunteer agent. When a victim needs help from a volunteer, he/she can broadcast a pre-set life status (well-being of the victim) or a customised text message to any volunteer near them. Ideally, if the volunteers are less than 30 metres away then the help can be provided at the earliest possibility. The literature has shown [113] that the ideal distance for wireless connectivity for smartphones is a maximum of 100 metres. This would be especially important when there is an interruption or absence in mobile networking and that smartphones would need to communicate with each other using an ad-hoc peer to peer connection.

My focus is to allow volunteers to help people within the radius of walking distance quickly and with the possibility to reduce the congestion of telecommunication network by sending structural text messages (not long voice conversation), following a structural, reliable communication protocol. This approach is especially useful to help victims quickly after a large-scale disaster as the messages are broadcasted to everyone near them, Inc. when most mobile connectivity is lost. The MKA system knows who are near them by using GNSS coordinates when there is network connectivity. The nearby volunteers can receive the ask-help messages if they are within 100 metres if the peer to peer connectivity is used. After volunteers receive the asking for help (ask-help) messages, they can either *Accept* to help or *Refuse* the request from the victim. The MKA system automatically applies the 3-way handshake communication protocol, by automatically sending the acknowledge messages *Acknowledge* back to the helper when the victim's system had received a reply from the helper (**Table 13** shows the protocol that applied 3-ways handshake). The helper's system would also confirm that he/she had received the *Acknowledge* message from the victim to ensure both the victim and volunteer know that their messages have been safely received.

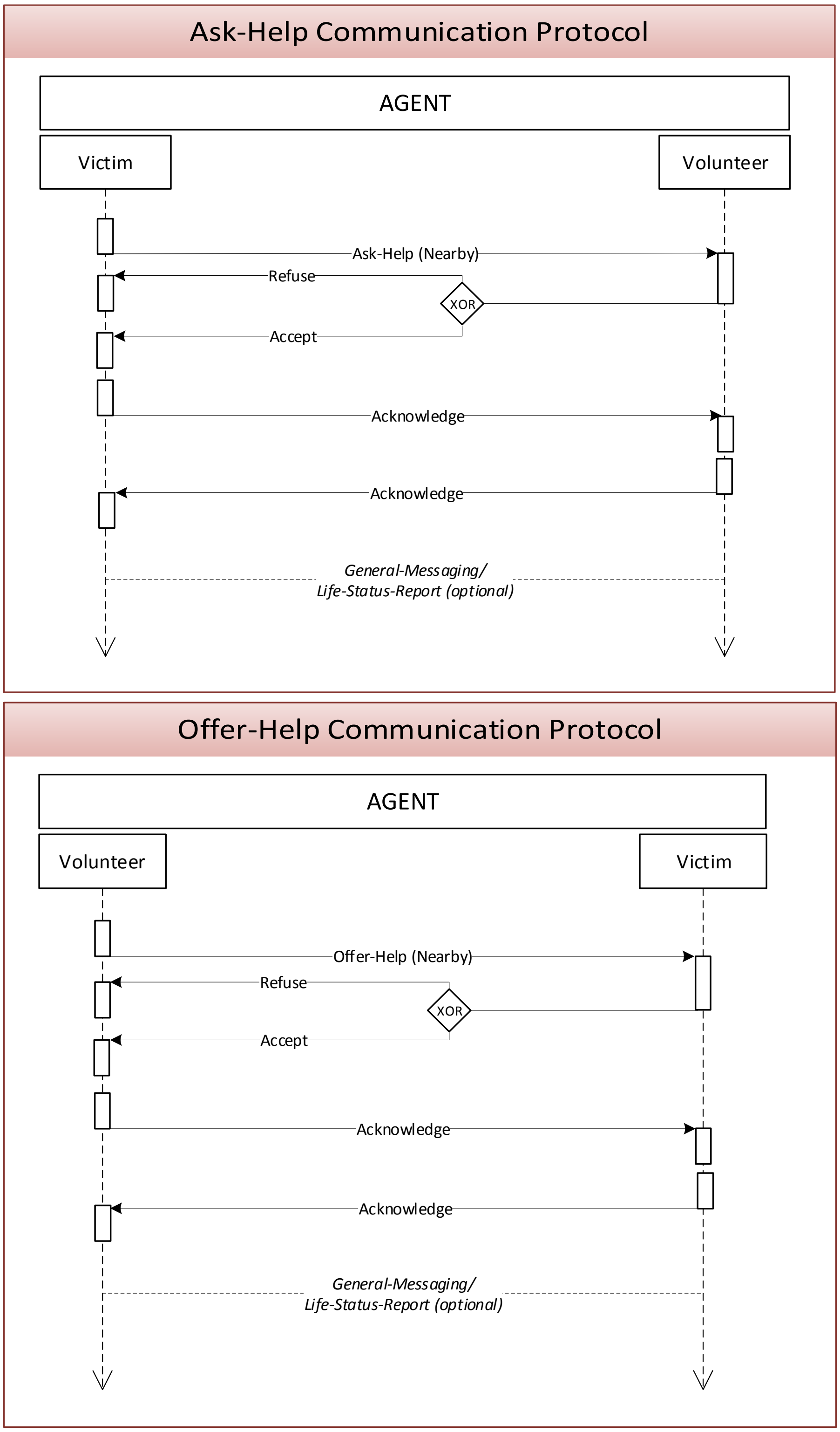


Figure 27: Ask-Help and Offer-Help Communication Protocol (Similar to the TCP 3-way Handshake Communication Protocol)

Table 13 : 3-Ways Handshake Applicable in ER-ACR

Item	Protocol	Description
1	Ask-Help	3-Way Handshake
2	Offer-Help	3-Way Handshake
3	Ask-Help-Forward	3-Way Handshake
4	General Messaging	Normal Handshake
5	Report Status	Normal Handshake

Figure 28 shows the performatives that have been used in the communication protocol in **Figure 27**.

Ask-help (
msg-id (UniqueID), *// unique ID of this message. Combination of sender*
// email-id, date and time
time-stamp (Local-date, Local-time), *//e.g. (20170531, 11:17)*
sender (Name, ID), *// name can be just first name, as ID is unique (e.g email*
// address)
receiver ((Name, ID) | nearby)), *// nearby is a* ***preset*** *word, it means there is no specific*
// receiver identified
expiration-date-time (expires), *// message expiry date/time*
myrole (“victim”),
content (conversation-id, *// combination of msg-id and auto number*
text-message (Free-text-message | “Please help me!!”), *// user typed or preset message*
life-status (“unhurt” | “injured” | “trapped” | “medicine needed” | “limited breathing space” | “rescued”), *// default is unhurt and trapped*
urgency (“Green” | “Amber” | “Red”), *// default is amber/set auto*
picture-message (PictureID), *// combination of* conversation-*id and auto number*
video-message (VideoID), *// combination of conversation-id and auto number*
voice-message(VoiceID) *// combination of conversation-id and auto number*
),

// GNSS coordinate is auto-generated, Address is free text and pre-entered by the user,
// e.g. work office, home, friends and family’s address, supermarket, places
// that the user frequents, including the height information, e.g. 1, 2 3rd floor. At the time
// of crisis, this information is automatically retrieved by the system from the local
// DB on the phone.

last-location (Real-time-GNSS-coordinate, Address), *// GNSS and address pair*
current-location (Real-time-GNSS-coordinate, Address), *// when no pairing is found,*
// Address is default to ‘unknown’
battery-status (Percentage-left), *// auto-generated*
message-status (1st-send | 2nd-send | n-send), *// continue sending, until the intended*
// receiver receives it and acknowledges it
channel (wifi-direct | multipeer) *// wifi direct (android) / multipeer*
// connectivity (iphone)
protocol (ask-help-and-reply), *// auto-generated*
ontology (OntologyID) *// e.g. URL address*
).

Offer-help (
msg-id (UniqueID), *// unique ID of this message. Combination of sender*
// email_id, date and time

time-stamp (Local-date, Local-time),   *//e.g. (20170531, 11:17)*
sender (Name, ID),   *// name can be just first name, as ID is unique (e.g email*
// address)
receiver ((Name, ID) | nearby)   *// nearby is a preset word, it means there is no specific*
// receiver identified
myrole ("volunteer" | "ER-worker" | "family/friend")
content (conversation-id,   *// combination of msg-id and auto number*
text-message (Free-text-message | "Are you okay? Please reply if you need help"),
// user typed or preset message
picture-message (PictureID),   *// combination of* conversation-*id and auto number*
video-message (VideoID),   *// combination of* conversation-*id and auto number*
voice-message(VoiceID)   *// combination of* conversation-*id and auto number*
),

// GNSS coordinate is auto-generated, Address is free text and pre-entered by the user,
// e.g. work office, home, friends and family's address, supermarket, places
// that the user frequents, including the height information, e.g. 1, 2 3rd floor. At the time
// of crisis, this information is automatically retrieved by the system from the local
// DB on the phone.

current-location (Real-time-GNSS-coordinate, Address),   *// when no pairing is found,*
// Address is default to 'unknown'
message-status (1st-send | 2nd-send | n-send),   *// continue sending, until the intended*
// receiver receives it and acknowledges it
channel (wifi-direct | multipeer)   *// wifi direct (android) / multipeer*
// connectivity (iphone)
protocol (ask-help-and-reply),   *// auto-generated*
ontology (OntologyID)   *// e.g. URL address*
).

Accept (
msg-id (UniqueID, ReplyID),   *// unique ID of this message. Combination of sender*
// email_id, date and time
time-stamp (Local-date, Local-time),   *//e.g. (20170531, 11:17)*
sender (Name, ID),   *//name can be just first name, as ID is unique*
receiver (Name, ID),
myrole ("victim" | "volunteer" | "ER-worker" | "family/friend")
content (conversation-id,   *// combination of msg-id and auto number*
text-message (Free-text-message | "I need help!! | "Wait, I will help you" | "I asked people nearby to help you"),   *// user typed or preset message*
life-status ("unhurt" | "injured" | "trapped" | "medicine needed" | "limited breathing space" | "rescued"),   *// default is unhurt and trapped*
urgency ("Green" | "Amber" | "Red"),   *// default is amber/set auto*
picture-message (PictureID),   *// combination of* conversation-*id and auto number*
video-message (VideoID),   *// combination of* conversation-*id and auto number*
voice-message(VoiceID)   *// combination of* conversation-*id and auto number*
),

// GNSS coordinate is auto-generated, Address is free text and pre-entered by the user,
// e.g. work office, home, friends and family's address, supermarket, places
// that the user frequents, including the height information, e.g. 1, 2 3rd floor. At the time
// of crisis, this information is automatically retrieved by the system from the local
// DB on the phone.

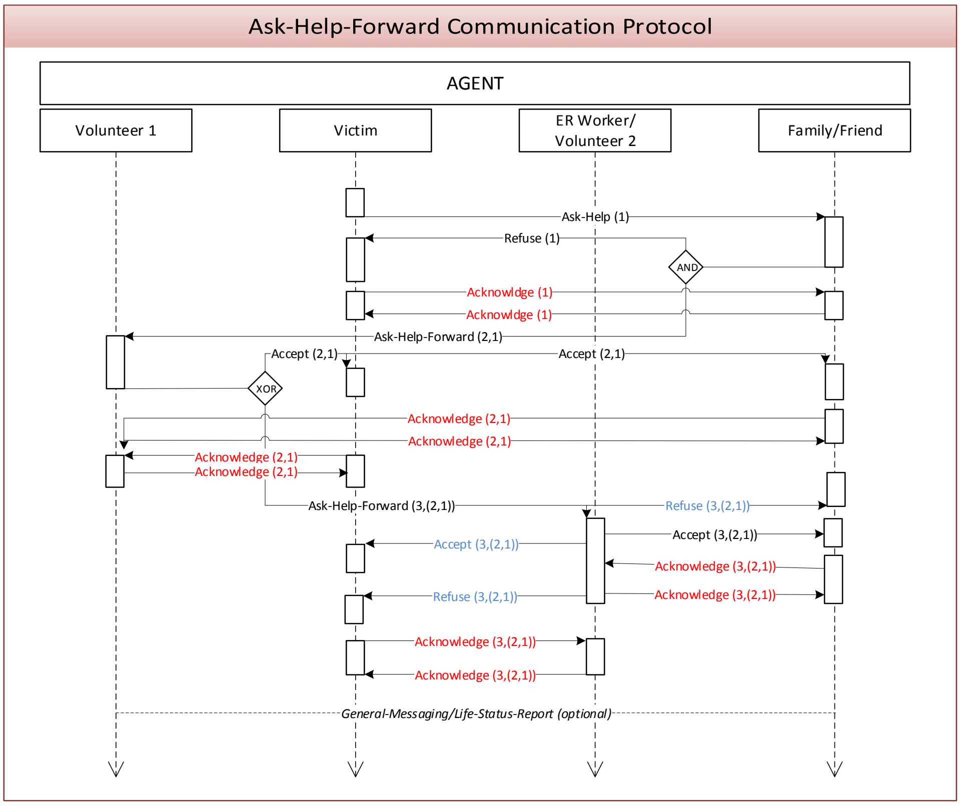
last-location (Real-time-GNSS-coordinate, Address),   *// GNSS and address pair*
current-location (Real-time-GNSS-coordinate, Address),   *// when no pairing is found,*
// Address is default to 'unknown'
battery-status (Percentage-left),   *// auto-generated*
message-status (1st-send | 2nd-send | n-send),   *// continue sending, until the intended*

```
                                                  // receiver receives it and acknowledges it
channel (wifi-direct | multipeer)                 // wifi direct (android) / multipeer
                                                  // connectivity (iphone)
protocol (ask-help-and-reply),                    // auto-generated
ontology (OntologyID)                             // e.g. URL address
).

Refuse (
msg-id (UniqueID, ReplyID),           // unique ID of this message. Combination of sender
                                      // email_id, date and time
time-stamp (Local-date, Local-time),  //e.g. (20170531, 11:17)
sender (Name, ID),                    //name can be just first name, as ID is unique
receiver (Name, ID),
myrole ("victim" | "volunteer" | "ER-worker" | "family/friend")
content (conversation-id,             // combination of msg-id and auto number
        text-message (Free-text-message | "Sorry, I can't help you'')
        forward-message (victim-message)
        ),
message-status (1st-send | 2nd-send | n-send),   // continue sending, until the intended
                                                 // receiver receives it and acknowledges it
channel (wifi-direct | multipeer)                // wifi direct (android) / multipeer
                                                 // connectivity (iphone)
protocol (ask-help-and-reply),                   // auto-generated
ontology (OntologyID)                            // e.g. URL address
).

Acknowledge (
msg-id (UniqueID, ReplyID),           // unique ID of this message. Combination of sender
                                      // email_id, date and time
time-stamp (Local-date, Local-time),  //e.g. (20170531, 11:17)
sender (Name, ID),                    //name can be just first name, as ID is unique
receiver (Name, ID),
content (conversation-id,
        text-message ("message received")
        ),
message-status (1st-send | 2nd-send | n-send),   // continue sending, until the intended
                                                 // receiver receives it and acknowledges it
channel (wifi-direct | multipeer)                // wifi direct (android) / multipeer
                                                 // connectivity (iphone)
protocol (ask-help-and-reply),                   // auto-generated
ontology (OntologyID)                            // e.g. URL address
).
```

Figure 28: Ask-Help and Offer-Help Structural Elements

3.6.3.2 Ask-Help Forward and Reply Communication Protocol

To show typical communication taking place among agents after a disaster, the victim often asks for help from his/her family and friends (**Figure 29**). However, in this scenario, the family or friend cannot help (right away), because they are not within the disaster area. So, this family/friend refuses the ask-help request but forward the message to another volunteer (volunteer 1) (that may be near the victim). If volunteer 1 is able to help, he/she will *Accept* the request and the accept message will be sent to the family/friend as well as the victim – so that everyone knows that the help is on his way. Acknowledge messages will also be exchanged between the sender (family/friend) and the victim to ensure the information has been received, and the victim is resting assured that the volunteer is coming to help. The ask-help message may be forwarded to another volunteer (e.g. volunteer 2 who is near the victim), if volunteer 1 refuses to help.



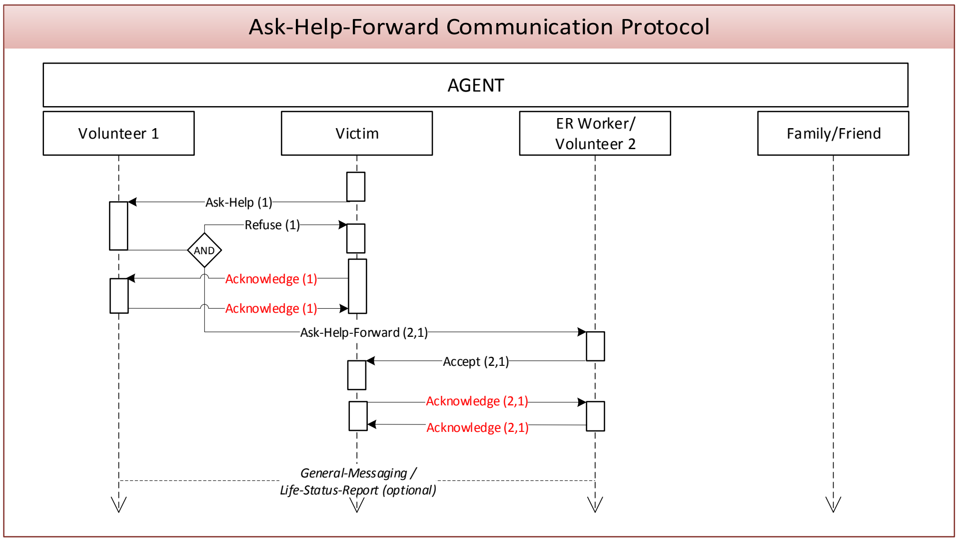


Figure 29: Ask-Help-Forward Communication Protocol

The following **Figure 30** shows the detailed content of the performatives used in the protocol in **Figure 29**.

Ask-help-forward (
msg-id (UniqueID), *// unique ID of this message. Combination of sender*
// email_id, date and time
time-stamp (Local-date, Local-time), *//e.g. (20170531, 11:17)*
sender (Name, ID), *// name can be just first name, as ID is unique (e.g email*
// address)
receiver ((Name, ID) | nearby)) *// nearby is a **preset** word, it means there is no specific*
// receiver identified
expiration-date-time (expires), *// message expiry date/time*
myrole ("volunteer" | "ER-worker" | "family/friend")
content (conversation-id, *// combination of msg-id and auto number*
text-message (Free-text-message | "Please help below victim"),
// user typed or preset message
forward-message (victim-message) *// victims message in full incl ID*
life-status ("unhurt" | "injured" | "trapped" | "medicine needed" | "limited breathing space" | "rescued"), *// default is unhurt and trapped*
urgency ("Green" | "Amber" | "Red"), *// default is amber/set auto*
picture-message (PictureID), *// combination of* conversation-*id and auto number*
video-message (VideoID), *// combination of* conversation-*id and auto number*
voice-message(VoiceID) *// combination of* conversation-*id and auto number*
),

// GNSS coordinate is auto-generated, Address is free text and pre-entered by the user,
// e.g. work office, home, friends and family's address, supermarket, places
// that the user frequents, including the height information, e.g. 1, 2 3rd floor. At the time
// of crisis, this information is automatically retrieved by the system from the local
// DB on the phone.
last-location (Real-time-GNSS-coordinate, Address), *// GNSS and address pair*
current-location (Real-time-GNSS-coordinate, Address), *// when no pairing is found,*
// Address is default to 'unknown'
battery-status (Percentage-left), *// auto-generated*
message-status (1st-send | 2nd-send | n-send), *// continue sending, until the intended*
// receiver receives it and acknowledges it
channel (wifi-direct | multipeer) *// wifi direct (android) / multipeer*
// connectivity (iphone)
protocol (ask-help-and-reply), *// auto-generated*
ontology (OntologyID) *// e.g. URL address*
).
Forward-message (*// forward message from victim*
msg-id (UniqueID),
time-stamp (Local-date, Local-time),
sender (Name, ID),
content (conversation-id,
text-message (Free-text-message | Preset-message), *// user typed or preset message*
life-status ("unhurt" | "injured" | "trapped" | "medicine needed" | "limited breathing space" | "rescued"), *// victim life-status*
urgency ("Green" | "Amber" | "Red"), *// victim urgency*
picture-message (PictureID),
video-message (VideoID),
voice-message(VoiceID),
expiration-date-time(expires),
last-location (Real-time-GNSS-coordinate, Address), *// victim last location*
current-location (Real-time-GNSS-coordinate, Address), *// victim current-location,*
battery-status (Percentage-left) *// victim battery-status*

```
        ),              // close content in forward-message
      ),                // close forward-message
    ).
```

Figure 30: Ask-Help-Forward Structural Elements

3.6.3.3 General Messaging Communication Protocol

The general messaging protocol gives a standard structure for general or arbitrary messaging where any agent can send or receive (customised) messages. Various performative such as *Send*, *Reply-to*, *Reply-With* are used in this protocol. (See **Figure 31**)

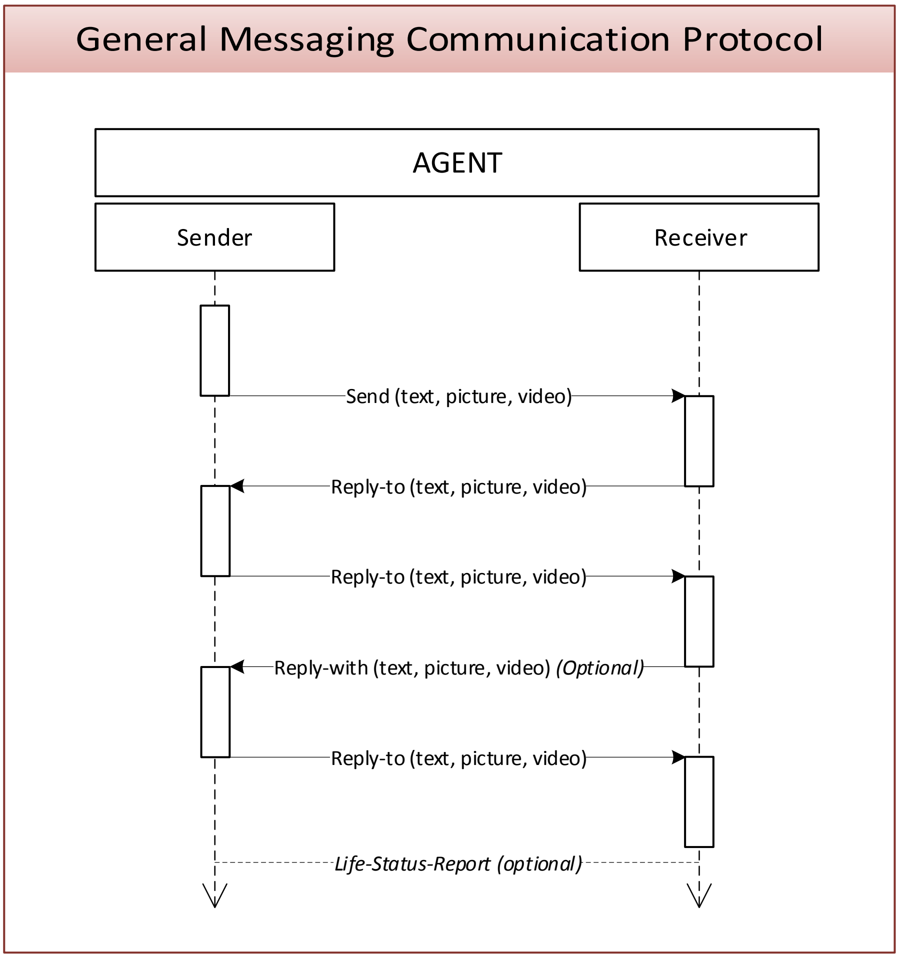


Figure 31: General Messaging Communication Protocol

Following **Figure 32** is a translation of the protocol in **Figure 31** to ER-ACL structural elements. The Reply-to performative replies to the same thread of messages from the same sender. Reply-with replies to the thread of messages (and maybe to the same sender) but would start with a new (relevant) topic.

```
Send (
msg-id (UniqueID),                        // unique ID of this message. Combination of sender
                                          // email_id, date and time
time-stamp (Local-date, Local-time),      //e.g. (20170531, 11:17)
sender (Name, ID),                        //name can be just first name, as ID is unique
receiver (Name, ID),
content (conversation-id,                 // combination of msg-id and auto number
        text-message (Free-text-message),
        picture-message (PictureID),      // combination of conversation-id and auto number
        video-message (VideoID),          // combination of conversation-id and auto number
        voice-message(VoiceID)            // combination of conversation-id and auto number
        ),
message-status (1st-send | 2nd-send | n-send),    // continue sending, until the intended
                                                  // receiver receives it and acknowledges it
channel (wifi-direct | multipeer)                 // wifi direct (android) / multipeer
                                                  // connectivity (iphone)
protocol (general-messaging),                     // protocol used
ontology (OntologyID)                             // e.g. URL address
).

Reply-to (
msg-id (UniqueID, ReplyID),                       // unique ID of this message. Combination of sender
                                                  // email_id, date and time
time-stamp (Local-date, Local-time),              //e.g. (20170531, 11:17)
sender (Name, ID),                                //name can be just first name, as ID is unique
receiver (Name, ID),
content (conversation-id,                         // combination of msg-id and auto number
        text-message (Free-text-message),
        picture-message (PictureID),              // combination of conversation-id and auto number
        video-message (VideoID),                  // combination of conversation-id and auto number
        voice-message(VoiceID)                    // combination of conversation-id and auto number
        ),
message-status (1st-send | 2nd-send | n-send),    // continue sending, until the intended
                                                  // receiver receives it and acknowledges it
channel (wifi-direct | multipeer)                 // wifi direct (android) / multipeer
                                                  // connectivity (iphone)
protocol (general-messaging),                     // protocol used
ontology (OntologyID)                             // e.g. URL address
).

Reply-with (
msg-id (UniqueID, ReplyID),               // unique ID of this message. Combination of sender
                                          // email_id, date and time
time-stamp (Local-date, Local-time),      //e.g. (20170531, 11:17)
sender (Name, ID),                        //name can be just first name, as ID is unique
receiver (Name, ID),
content (conversation-id,                 // combination of msg-id and auto number
        text-message (Free-text-message),
        picture-message (PictureID),      // combination of conversation-id and auto number
        video-message (VideoID),          // combination of conversation-id and auto number
        voice-message(VoiceID)            // combination of conversation-id and auto number
        ),
message-status (1st-send | 2nd-send | n-send),    // continue sending, until the intended
                                                  // receiver receives it and acknowledges it
channel (wifi-direct | multipeer)                 // wifi direct (android) / multipeer
```

```
                                                   // connectivity (iphone)
protocol (general-messaging),                      // protocol used
ontology (OntologyID)                              // e.g. URL address
).
```

Figure 32: General Messaging Structural Elements

3.6.3.4 Report Status Communication Protocol

Figure 33 shows the life status report protocol. This protocol will apply automatically when a volunteer accepts an ask-help request. The system will send the victim's life status periodically to a particular volunteer and in randomised time to minimise network congestion. This messaging will stop when it is manually stopped by the victim, or when the situation is changed (e.g. victim is rescued). This is a one-way automatic report and there is no conversation taking place.

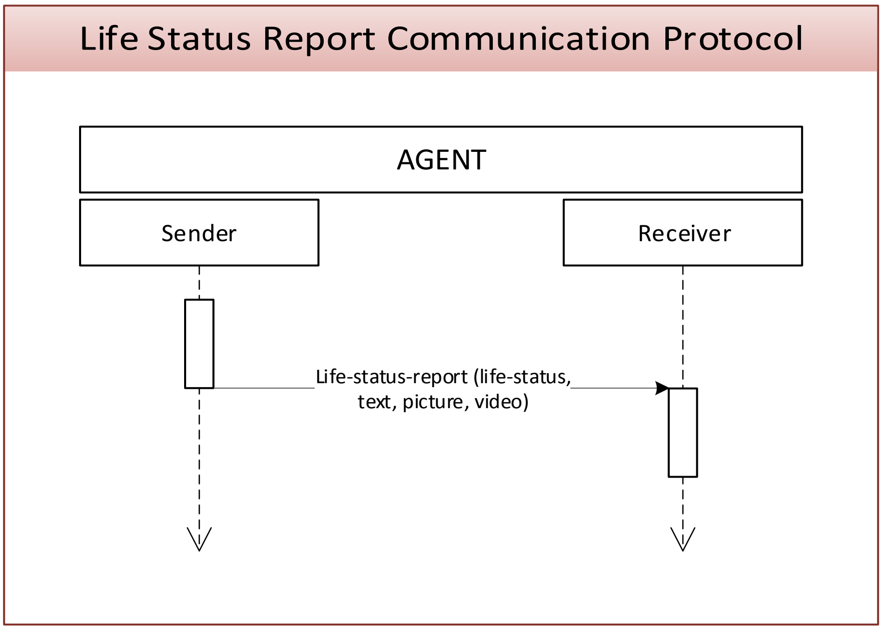


Figure 33: Life-Status-Report Communication Protocol

Following **Figure 34** is a translation of the protocol in **Figure 33** to ER-ACL structural elements.

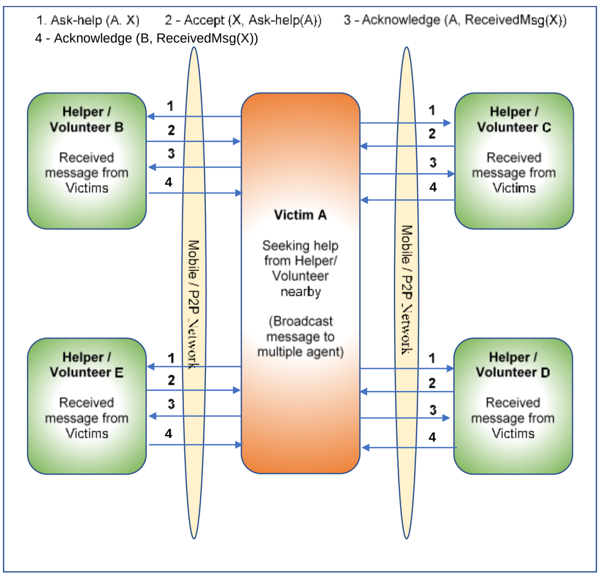
```
Status-report
msg-id (UniqueID),                        // unique ID of this message. Combination of sender
                                          // email_id, date and time
time-stamp (Local-date, Local-time),      //e.g. (20170531, 11:17)
sender (Name, ID),                        //name can be just first name, as ID is unique
receiver (Name, ID),
content (conversation-id,                 // combination of msg-id and auto number
```

text-message (Free-text-message),
life-status ("unhurt" | "injured" | "trapped" | "medicine needed" | "limited breathing space" | "rescued"), *// default is unhurt and trapped*
urgency (Green| Amber| Red), *// default is amber/set auto*
picture-message (PictureID), *// combination of conversation-id and auto number*
video-message (VideoID), *// combination of conversation-id and auto number*
voice-message(VoiceID) *// combination of conversation-id and auto number*
),
last-location (Real-time-GNSS-coordinate, Address), *// GNSS and address pair*
current-location (Real-time-GNSS-coordinate, Address), *// when no pairing is found, // Address is default to 'unknown'*
battery-status(Percentage-left), *// auto-generated*
time-gap-from-last-message (minute) *// time gap in minute*
channel (wifi-direct | multipeer) *// wifi direct (android) / multipeer // connectivity (iphone)*
protocol (report-status), *// protocol used*
ontology (OntologyID) *// e.g. URL address*
).

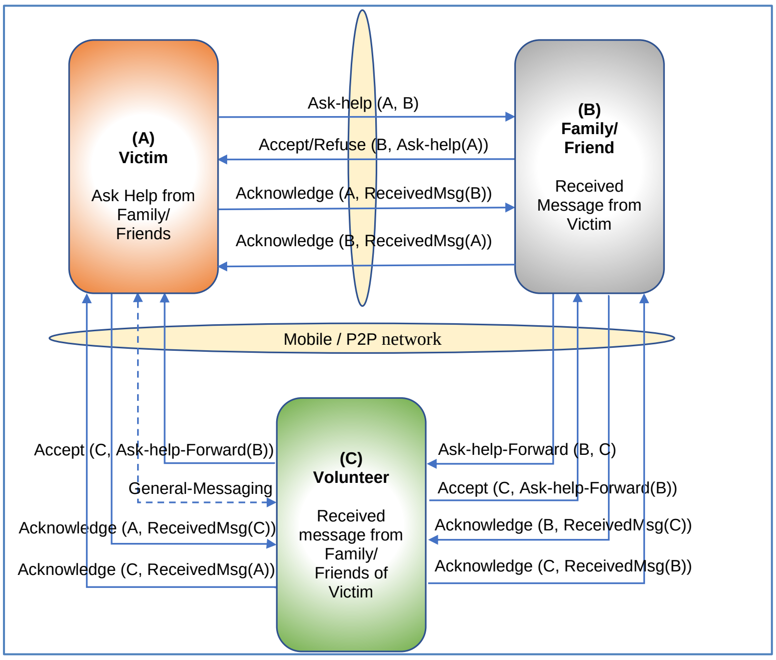
Figure 34: Life-Status-Report Sructural Elements

3.6.4 Emergency Response Scenarios Agent Communication Protocol using Mobile/Peer to Peer Network

In this section, I provide the ask-help communication scenario as in **Figure 35(a)** where the victim agent broadcasts ask-help message to all volunteers near them, and a complex ask-help-forward scenario in **Figure 35(b).** The complex scenario begins with the victim asking help from their family, but they can't help them. In this scenario, the family will forward ask-help message to volunteer nearby to help the victim.



(a)



(b)

Figure 35: Simple, Complex Ask-Help and Forward Communication Protocol in ER-ACL and Scenario

The following **Figure 36** shows how I apply performative and parameters in the example scenario.

Ask-help (
msg-id ("1"), *// unique ID of this message*
time-stamp (("20170531"), ("11:17")), *//e.g. (20170531, 11:17)*
sender ("john", "john@gmail.com"), *// name can be just first name, as ID is unique (e.g email address)*
receiver (broadcast) *// nearby is a **preset** word, it means there is no specific // receiver identified*
role ("victim")
content ("1",
  text-message ("" | "Please help me"), *// user typed or preset message*
  forward-message ("")
  life-status ("injured"), *// default is unhurt and trapped*
  urgency ("Amber"), *// default is amber*
  picture-message (""),
  video-message ("")
  ),

// GNSS coordinate is auto-generated, Address is free text and pre-entered by the user,
// e.g. work office, home, friends and family's address, supermarket, places
// that the user frequents, including the height information, e.g. 1, 2 3rd floor. At the time
// of crisis, this information is automatically retrieved by the system from the local
// DB on the phone.

last-location (("55.9449402", "-3.1872813"), "50 Potterrow, Edinburgh EH8 9BT"),
// GNSS and address pair
current-location (("55.9445975", "-3.1872704"), "Informatics Forum, 10 Crichton St, Edinburgh EH8 9AB"), *// when no pairing is found,*
// Address is default to 'unknown'

battery-status ("40%"), *// auto-generated*
message-status ("1st-send"), *// continue sending, until the intended*
// receiver receives it and acknowledges it
protocol (ask-help-and-reply), *// auto-generated*
ontology (CTO) *// e.g. URL address*
).

Accept (
msg-id ("1", "1"), *// unique ID of this message*
time-stamp (("20170531"), ("11:27")), *//e.g. (20170531, 11:17)*
sender ("bob", "bob@gmail.com"), *//name can be just first name, as ID is unique*
receiver ("john", "john, john@gmail.com"),
role ("volunteer")
content ("1",
text-message ("", "" | "", "What is your condition?") *// user typed or preset message*
forward-message ("")
life-status ("", "", "" , "" , "", ""), *// default is unhurt and trapped*
urgency ("Green" | "Amber" | "Red"), *// default is amber*
picture-message (""),
video-message ("")
),

// GNSS coordinate is auto-generated, Address is free text and pre-entered by the user,
// e.g. work office, home, friends and family's address, supermarket, places
// that the user frequents, including the height information, e.g. 1, 2 3rd floor. At the time
// of crisis, this information is automatically retrieved by the system from the local
// DB on the phone.

last-location (("55.9444089," "-3.1870694"), "Informatics Forum, 10 Crichton St, Edinburgh EH8 9AB"), *// when no pairing is found,*
// Address is default to 'unknown'
battery-status (60%), *// auto-generated*
message-status ("1st-send"), *// continue sending, until the intended*
// receiver receives it and acknowledges it

protocol (ask-help-and-reply), *// auto-generated*
ontology (OntologyID) *// e.g. URL address*
).

Acknowledge (
msg-id ("1", "1"), *// unique ID of this message*
time-stamp (("20170531"), ("11:27")),, *//e.g. (20170531, 11:17)*
sender (("john", "john@gmail.com")), *//name can be just first name, as ID is unique*
sender ("bob", "bob@gmail.com"), ,
content (conversation-id,
text-message ("message received")
),
message-status ("1st-send"), *// continue sending, until the intended*
// receiver receives it and acknowledges it
protocol (ask-help-and-reply), *// auto-generated*
ontology (OntologyID) *// e.g. URL address*
).

Figure 36: Ask-Help-Forward Communication Protocol

3.7 Summary

In this chapter, I described the formal framework and research methodology, where the methodology includes five main research phases based on the project objectives as follows:

i. Initial study: the background of the problem and some ideas related to the problem was given and solving respectively.
ii. Analysis and Design Phase: analysed all of the technologies and the way we're using for conducting this research.
iii. MKA Response Framework Development Phase: a communication framework development was discussed.
iv. CTO Ontology Development Phase: an ontology development was discussed.
v. ER-ACL Development Phase: ER-Agent Communication Language development was discussed.

Chapter 4 – Mobile Kit Disaster Assistant (MKA) System Requirements and Design

4.1 Introduction

To demonstrate that the formal framework described previously is realistic and can work well in practice, I have created a mobile MKA system for this purpose. To begin with, I have generated draft user requirements to get early expert and potential user feedback to identify suitable functions that the system will require. In addition, I have also provided an initial system and user interface designs to get user feedback. Details of system evaluations and user feedback are described in **Chapter 5**.

This chapter, therefore, describes the system requirements, design and implementation of the MKA System. This chapter also covers the development and design phases of the MKA system. First, the system development steps mentioned in Research Methodology in **Figure 8 (Chapter 3)** are described in this chapter. The requirement and the development phases include three main steps beginning with the step which covers the system requirements, the modelling phase that provides a design of UML diagrams of the MKA system and finally, the third step that is the implementation and the user interfaces.

4.2 Functional Requirements of Mobile Kit Disaster Assistant System

"*A functional requirements are techniques aimed at determining the system components, attribute, and identifying the requirements that fulfil the required output*" [114]. "*Functional requirements identify the system components, attributes that are required to achieve the intended results*" [115]. The objectives of determining functional requirements are to:

- Identify the user requirements
- Identify the other requirements known as non-functional requirements

All of the system components must be identified at the system requirement gathering stage itself [116]. The hardware and software requirements related to building, compiling and the use of MKA system, in terms of hardware and software used. All of the requirements for the MKA system may be prioritised as critical, significant and secondary functions. These different levels of priorities define the importance of the requirements for the overall application.

4.2.1 Critical Functional Requirements

These requirements describe the core functionalities of the MKA system. Without meeting these requirements, the application will be unusable to meet its intended purposes. These requirements, therefore, are the most critical requirements to meet. MKA mobile app's target requirements are stated in **Table 14** below.

4.2.2 Significant Functional Requirements

Significant requirements are functionalities that are highly important to the MKA system. The system will perform only basic core functionalities if these requirements are not met. Without meeting these requirements, the application would be considered as a functional system.

4.2.3 Secondary Functional Requirements

Secondary requirements include 'nice to have' functionalities. These non-vital requirements are not fundamental to the core functions of the MKA system, however, they will provide a number of extra features and functionalities that will enhance the application further from its basic core functionality.

4.2.4 MKA System Requirements

Table 14: Requirements for MKA system

Item	Requirements	Priority
1	The apps would utilise the smartphone basic features such as GNSS receiver, alarm, voice, messaging, camera, gestures.	Critical
2	The apps would be able to communicate with each other using explicit messages that are short and to the point – to avoid unnecessary telecom congestion	Critical
3	The apps would suggest a suitable (but simple) actions need to be taken during and after the disaster.	Critical
4	The apps and data storage must be distributed and functioning in every device to make sure all the information can be accessed even when there is no internet connection	Critical
5	Related data and emergency information must be given well-defined meaning in structural languages. Machines must be able to interpret it meaningfully.	Critical
6	The app would keep sending pre-set messages automatically as appropriate, e.g. if the messages have not been replied or acknowledged, after they were first sent by victims. Random time should be used by each device in order to reduce network congestion until helpers accepted the request.	Critical
7	The application would compile correctly and run on the smartphone (iPhone or Android)	Significant
8	The app would be able to provide a robust communication mechanism, e.g. using a reliable communication protocol, so that senders know that his/her messages have been safely delivered to the targeted recipients, etc.	Significant
9	The mobile app should use an appropriate level of power consumption to reduce battery usage so that the communication can remain as long as possible, as needed.	Significant

4.3 System Modelling and Design

In this section, the design of the system is illustrated in the Use Case Diagram to allow readers to understand and view the MKA system from a different perspective and in varying degrees of abstraction. Use Case Diagram is used to analyse high-level system requirements, as high-level view and also part of Unified Modelling Language (UML) diagram and commonly created in visual modelling tools, including Use Case Diagram, Sequence Diagrams and class diagram [117].

The use-case focuses on the requirements of a system rather than the way a system will actually be designed. A use case diagram shows the interactions among users and a system via scenarios. It displays how actors may use the system and the activities that they may carry out using the system. **Figure 37** shows a use case diagram for the MKA system.

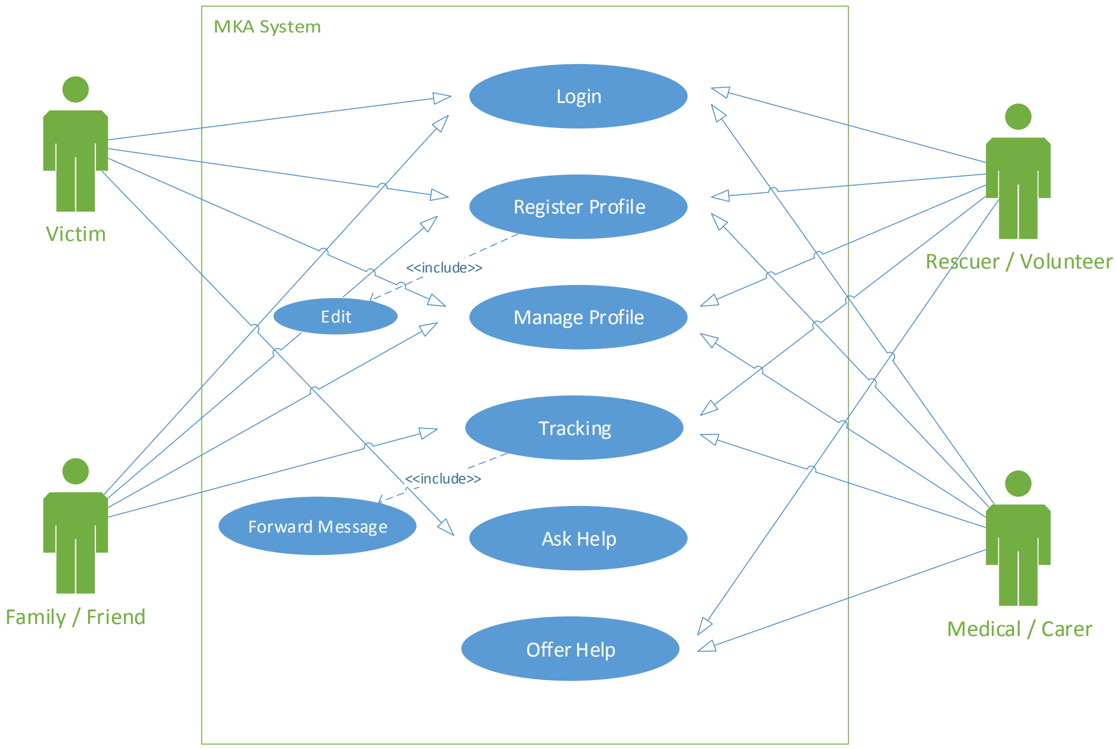


Figure 37: MKA System Use Case Diagram

4.4 Design of User Interface

To develop the MKA system, a survey was carried out with fourteen potential users - ten of them are adults (more than 18 years old) and four of them are children (less than 17 years old) were involved in the survey. From the mixed category, various view and opinion were collected especially on children. This is important to facilitate MKA users, including children and adults to use the app.

Firstly, briefing and presentation were given that is about the design, features and system flow was conducted with the participant to make sure that they understand the objectives of the study and they will have some ideas of what the MKA system is meant for and what features are provided in the MKA mobile apps. After that, a question and answer session together with short discussion was done to make sure they understood the questions and how to answer the survey forms (Please see Survey Form in **Appendix 1**). The results of the survey are discussed in **Section 5.2.3**.

The MKA system interface design was designed using Balsamiq Wireframes [118]. It is a mock-up tool for User Design (UD) processes. It was used during the design phase of the MKA system. The advantages of wire framing is that it provides an early visualisation that can be used to review with users. They would review it and provide feedback via MKA's system design survey.

The participation in the study is entirely voluntary, and responses are strictly confidential. There is no foreseeable risk associated with providing a survey for this project. Below are the captured screens presented to the participants.

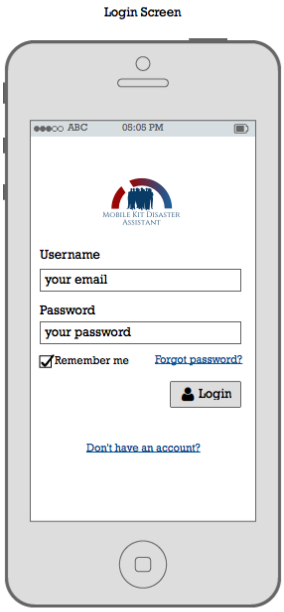
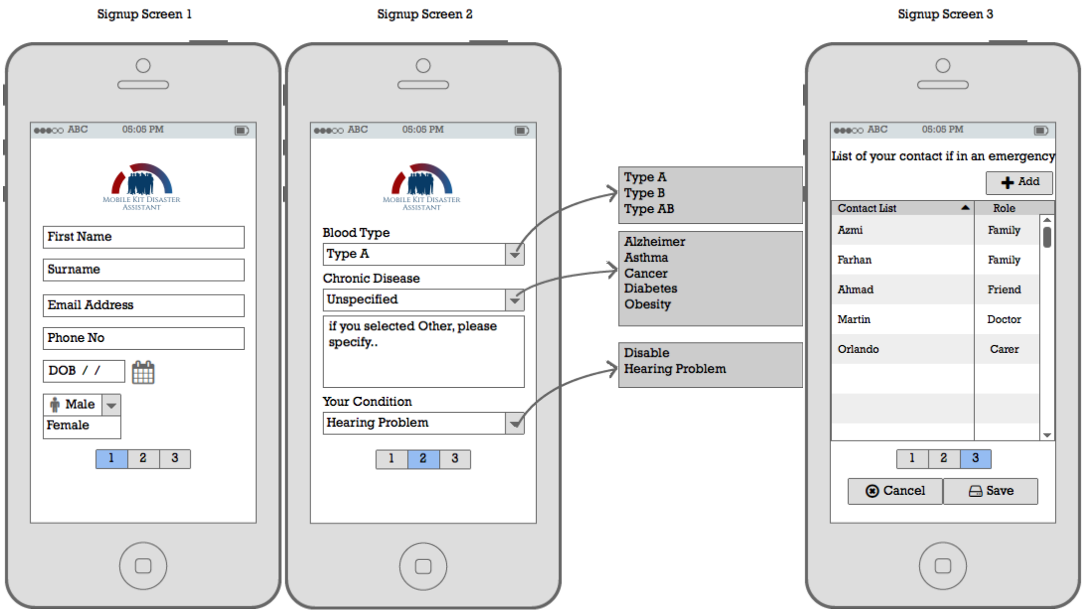


Figure 38: Login Screen

Figure 38 shows the login screen. Users must log in to the apps for the first time use after the registration was done.



(A) (B) (C)

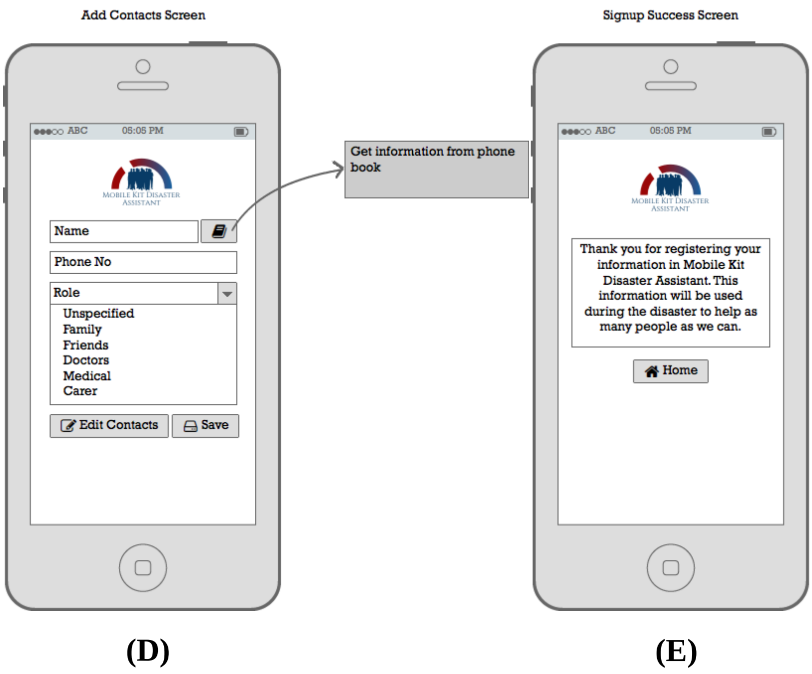


Figure 39: Signup Screen

Users who do not register cannot use the system. It is important to make sure that the system must have user profile records to help them during an emergency. Some of the inputs must be key in by the users such as first name, surname, email address, phone no, date of birth, gender, blood type, any chronic disease and etc.

Figure 39 (A) - (E) shows profile information screens in MKA system.

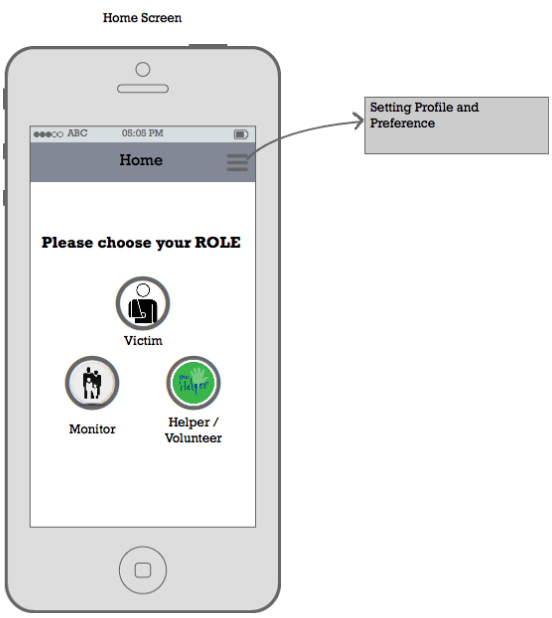


Figure 40: Home Screen

After the MKA system is activated, the Home screen as in **Figure 40** will appear and users must choose their roles in this situation. There are three main roles in this system which are the victim, volunteer or monitor (want to monitor their family and close friends only).

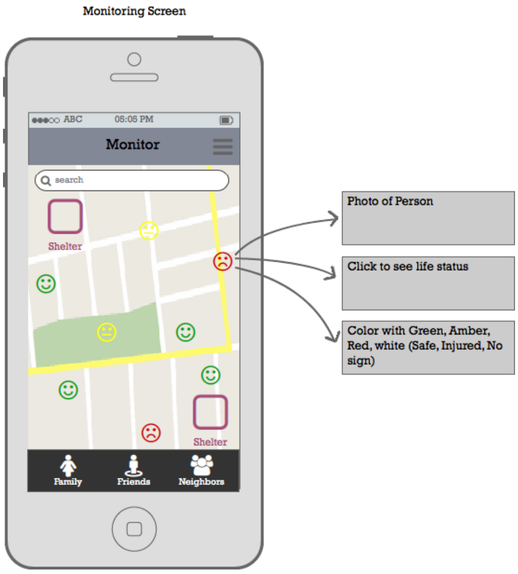


Figure 41: Monitoring Screen

The screen shown in **Figure 41** will appear when the user chooses a monitoring role. This module allows users to monitor their family, friends/neighbour when in an emergency. There are three icon colours that will represent a victim's well-being status - red is "no-sign" status (no response), yellow for injured and green is safe.

Figure 42: Volunteer / Helper Screen

This screen in **Figure 42** is for users who have taken Helper/Volunteer roles. This module will help helpers to broadcast messages to nearby victims and find people who need help. There are different shapes and colours for this module. It, therefore, should be easier for helpers to recognise victims.

Figure 43: Monitor Family and Friends Status Screen

Users who want to monitor their family are allowed by clicking the appropriate icon in **Figure 41**. After that, the module in screen **Figure 43** will appear to show the status of victims. Victims can communicate with helpers by using text, picture or video. This would help them to inform helpers where there are. Users can also communicate with helpers who are nearby using the "broadcasting message" function of the system. Maps in this module help a user (e.g. a family or friend) to find a helper near the victim.

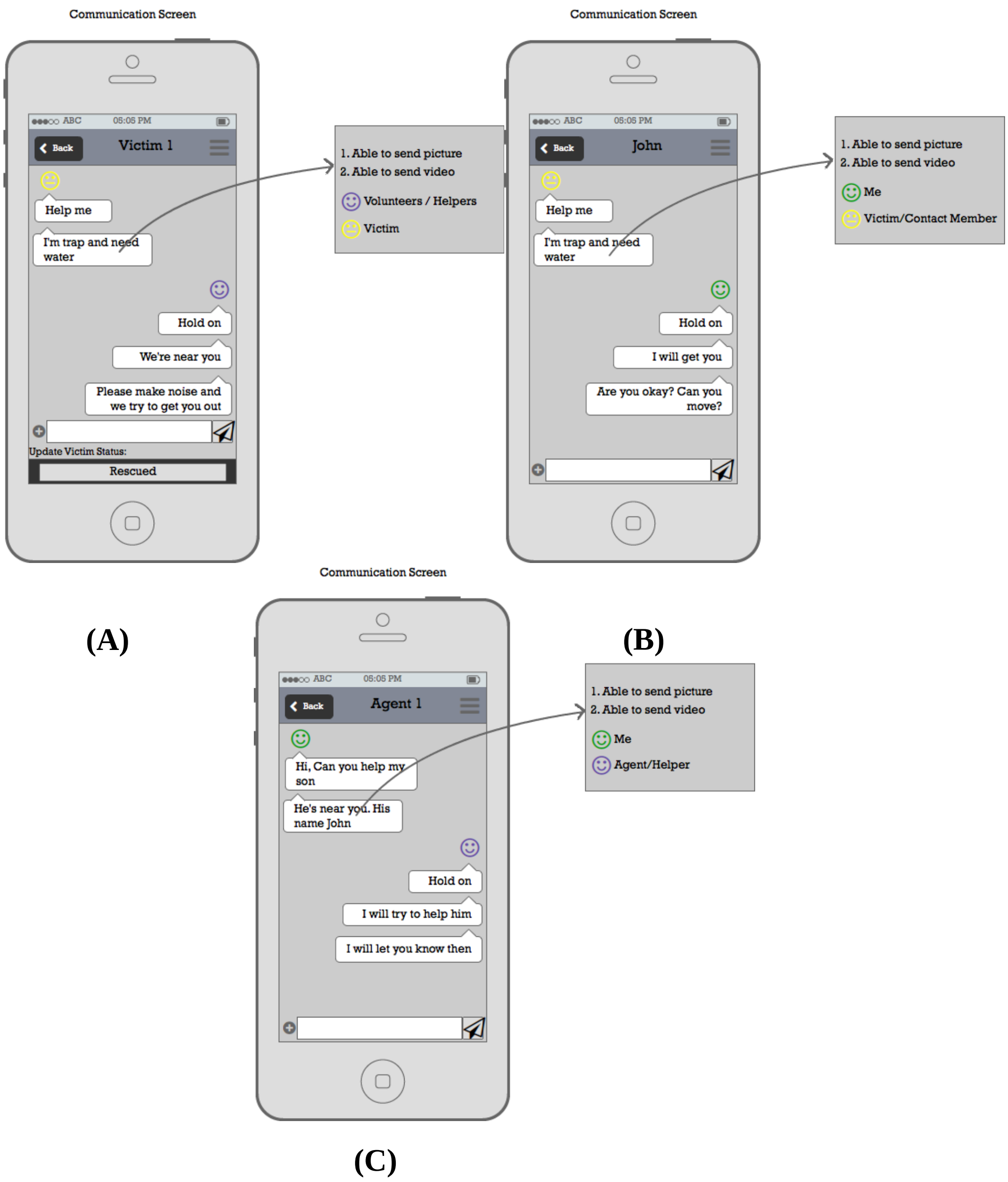


Figure 44: Communication between Agent and Victim Screen

In order to allow people to communicate using a single system, the MKA system was designed for users to be able to text, send picture and videos even in offline mode. With communication features available within the system, it allows helpers and victims to communicate e.g. to know the exact location of victims or any nearby landmarks to make helpers find them easily. **Figure 44 (A) – (C)** shows the communication screen between a victim and his/her helper and family in MKA system.

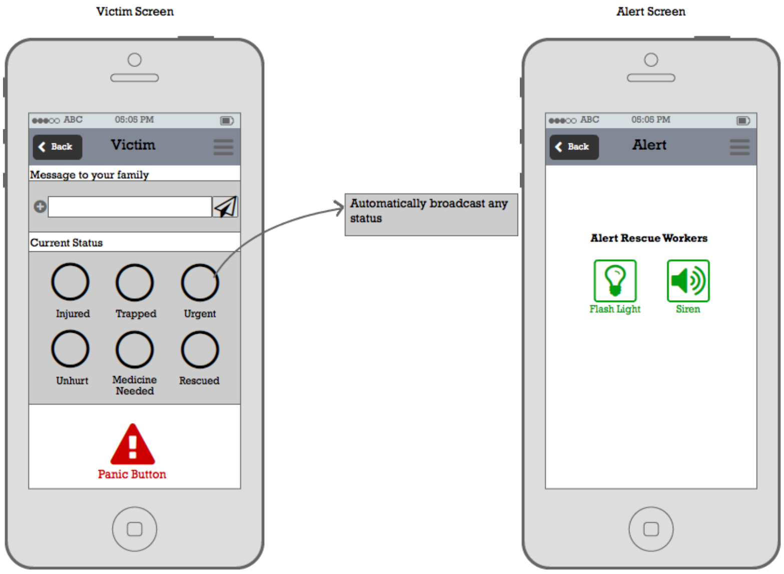


Figure 45: Victim Screen

Figure 45 presents the victim's screen that allows a victim to broadcast messages to nearby helpers or send it to their family. There are three main components in this screen. On the top of the screen is a direct message to their family, and below a custom message textbox contains pre-sets messages ready for the victim to click and broadcast. The last component is a panic button which sends alert to his/her helper that is very important for helpers to trace the exact location of the victim.

4.5 Final Implementation of User Interface

The previous sections describe the draft User Interface and user feedback and evaluation of them. This section describes the final user interfaces and functionalities that have been implemented in the final MKA system. After the evaluation and feedback from potential users on wireframe screens in **Section 5.2.3**, some of the label and screen design was slightly changed to make users easier understand the functions of the buttons provided in the MKA system. For example, the label (agent role) *Monitor* in **Figure 40** has been changed to *Family & Friends;* and the (agent roles of) *Rescuer/Public Volunteer* and *Medical/Social Carer* are now grouped as Helper as in **Figure 46**, **Figure 47** and **Figure 50** to improve clarity. However, the functions of the buttons remain the same.

Figure 46 and **Figure 47** gives an overview of how the MKA mobile app may be used:

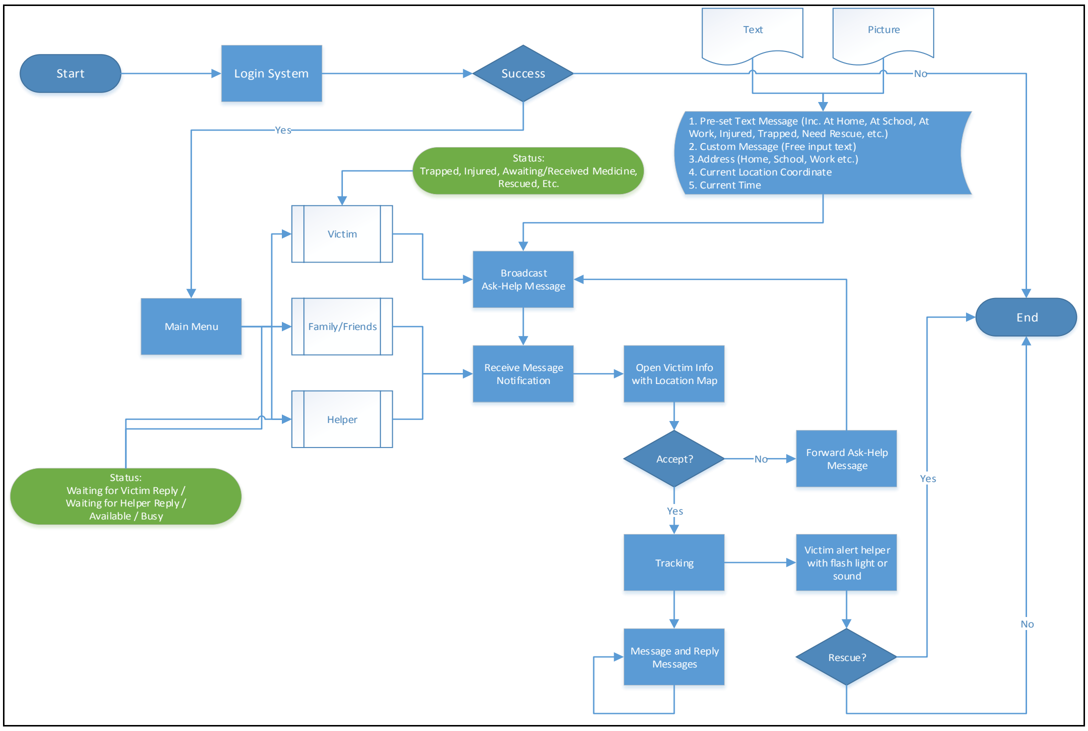


Figure 46: An overview of UI of MKA system when Mobile Network is available

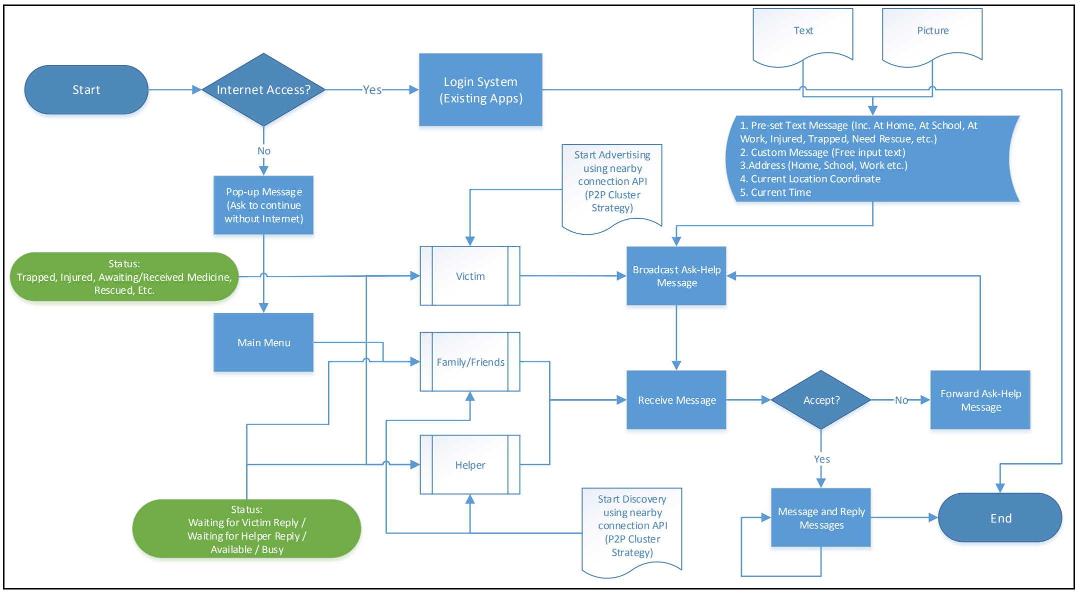


Figure 47: An overview of UI of MKA system when no Mobile Network is available

The MKA system has been successfully and completely developed for Android device and met all of the requirements as defined at the functional requirements level. It was implemented using Android Studio (AS) [119] by Google. The code was written in Java and Firebase [120] as a google cloud database platform.

AS is the official tools and an Integrated Development Environment (IDE) for developing applications for Android platforms. The editor tool for creating User Interface (UI) is very strong. The emulators provided in AS support various Android OS versions and easier to test and simulate the MKA system without having an actual Android device.

Firebase is one of the Mobile Backend as a Service (MBaaS). MBaaS is a medium that offers a way to link the mobile applications to the backend cloud storage and backend APIs. It is known as Backend as a Service (BaaS) because it is offering features such as sending push notifications. Firebase is great for prototyping application development. Developers do not need to code for server-side APIs. An Authentication rule is simple and even developers don’t have to worry about the constraints (rules enforced on the data columns or tables) on DB. **Figure 48** below shows the architecture of MKA system.

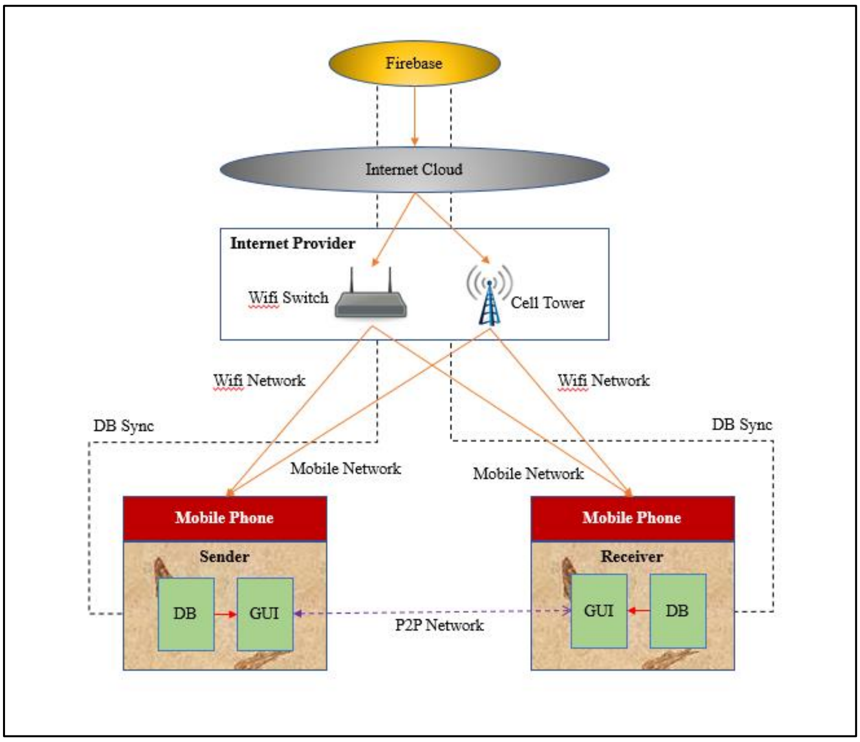
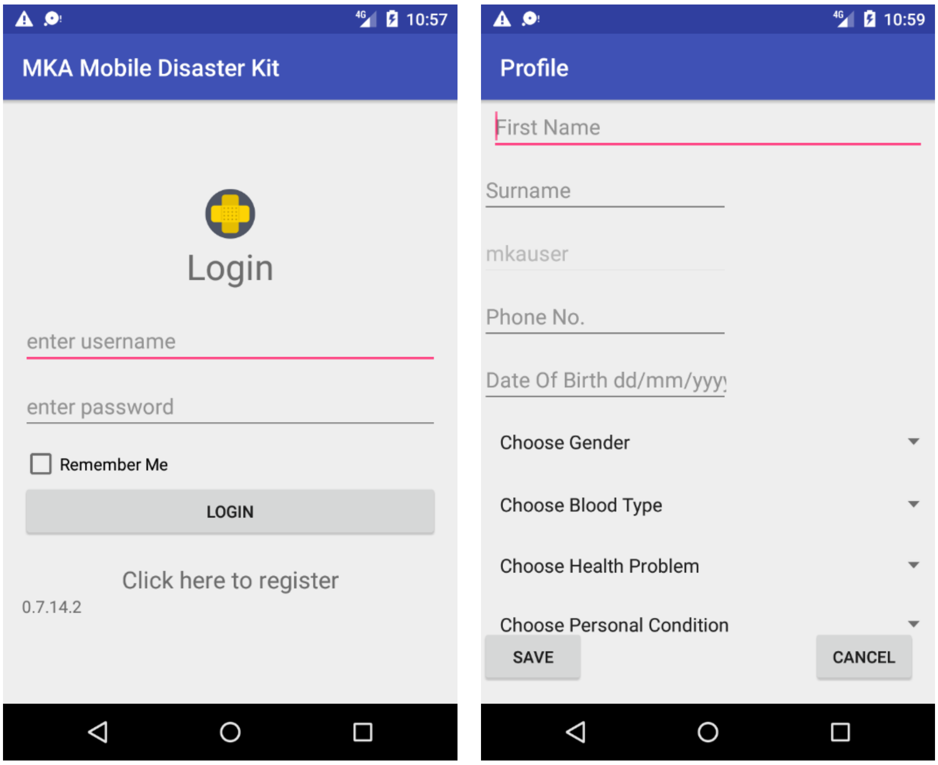


Figure 48: MKA System Architecture

Some of the snapshots of the MKA system are depicted in **Figure 49** to **Figure 53** respectively.

A. Login Screen

This is the first screen **(Figure 49 (A))** for the user when accessing the system. The users are required to install the MKA system and registered using their Android phone to gain access to the system. In the *Login* screen, the password entered by the user will be displayed with dots, instead of plain text. Once a user enters his/her username and password, it will be checked and verified against the user information stored. If successful, first-time login user will be forwarded to the *Profile Registration* screen to record their personal profile **(Figure 49 (B))**. Then, MKA system will start executing the *Main Menu* and operations offered by the system.



(A) Login (B) Profile Record

Figure 49: Login and Profile Record Screen

B. Main Menu Screen

Figure 50 illustrates the *Main Menu* interface of the MKA system. This is the second screen displayed for the user after they successfully login to the system. The user can choose their role from three main roles provided in MKA system. As one can see, the monitor role had been removed, as its functions are subsumed by the helper role. In addition, as family and friends would have different meaning and functions to the victim, they are being given an independent role.

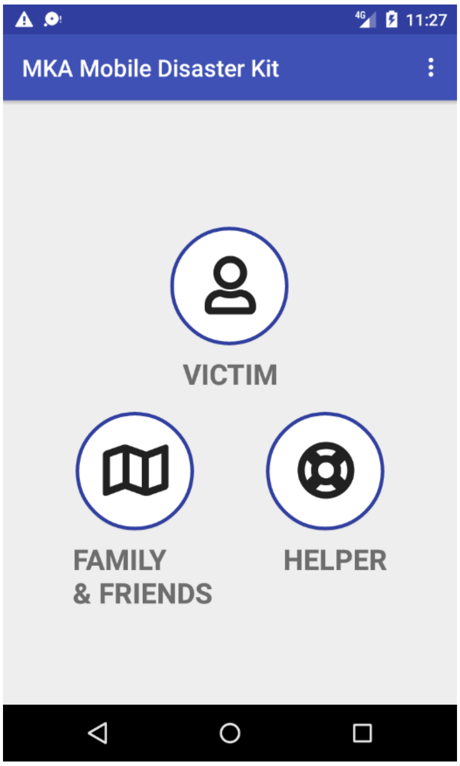
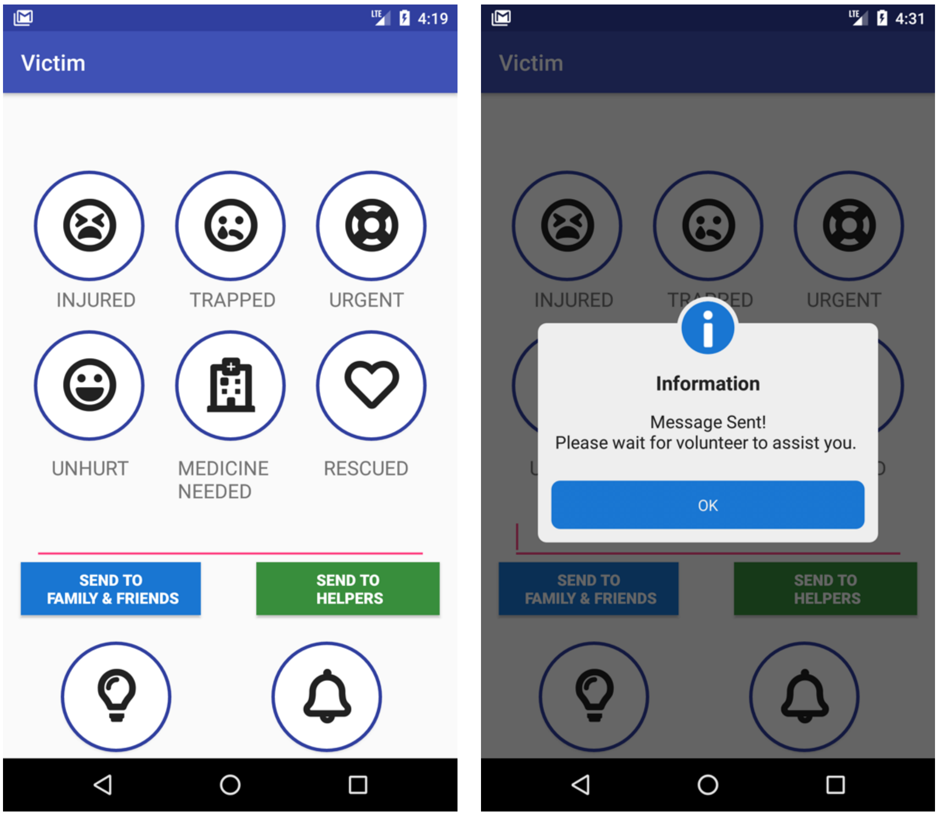


Figure 50: Main Menu Screen

C. Victim Role Screen

The screen provided in **Figure 51(A)** shows the victim's role screen where a victim can either choose a pre-set message or sending a free text message to send to helpers or their family and friends. At the bottom of the screen, the MKA system provides two important tools to make helpers easier to find them (e.g. flashlight and Siren). A sent pop-up message will appear on the screen after the message has been sent successfully (**Figure 51(B)**).

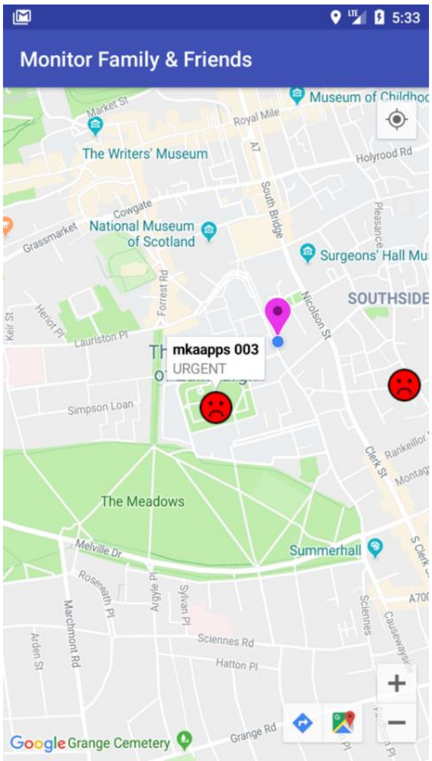


(A) Victim Role (B) Pop-up Message

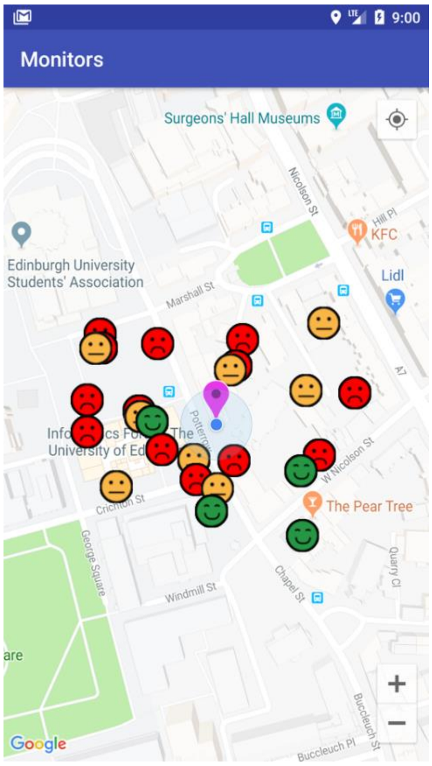
Figure 51: Victim Role and Pop-up Message Screen

D. Family/Friends and Helper Role Screen

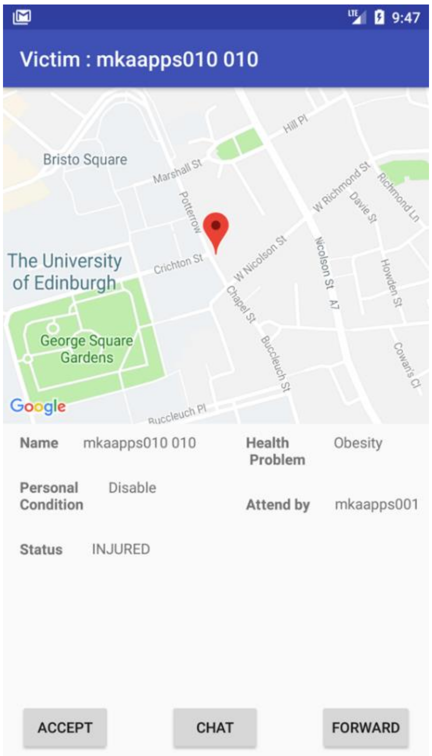
The main function of the MKA system is to track people in an emergency. **Figure 52** shows the maps in *Family/Friends* as in **Figure 52(A)** screen and *Helper* screen in **Figure 52(B)**. From this screen, family/friends are allowed to trace his/her family/friends only. While as a helper, the map will show all victims that are nearby the helper indicated with three main colours (i.e. Red, Amber and Green). Helpers or the victim's family can click an icon to get a victim's information as stored in their profile **(Figure 52(C))**. From that, helpers will know more about the victim including a summary of his/her health background. This screen is very important to enable helpers or rescue teams to do the best preparation they can to save the victim.



(A) Family/Friends



(B) Helper



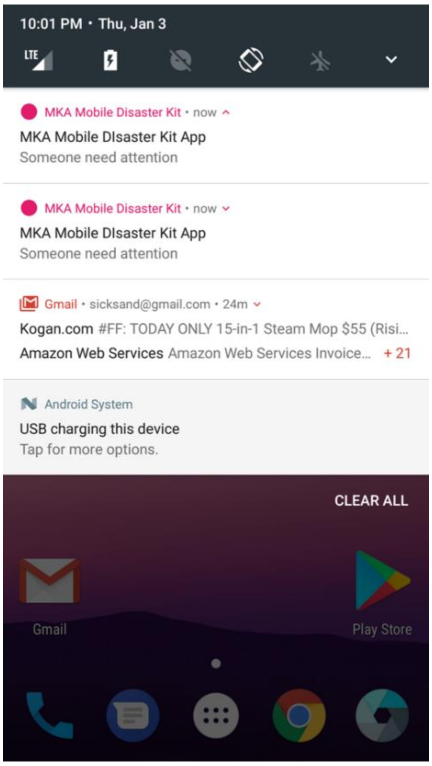
(C) Accept / Refuse

Figure 52: Family/Friends, Helper and Accept/Refuse Screen

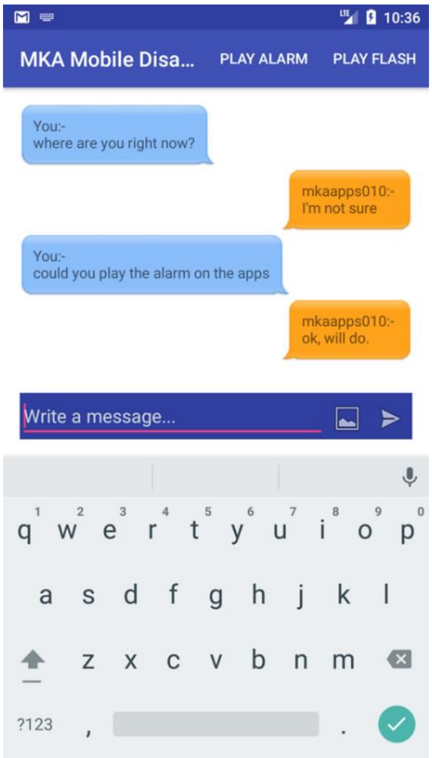
E. Notification and Messaging Screen

The MKA system uses push-notifications to alert helpers' possible actions that need to be taken. The notifications in **Figure 53(A)** shows the *Helper's* screen displays notifications sent by the victims. Such push notifications will appear on helper's smartphones with MKA system activated or running in the background.

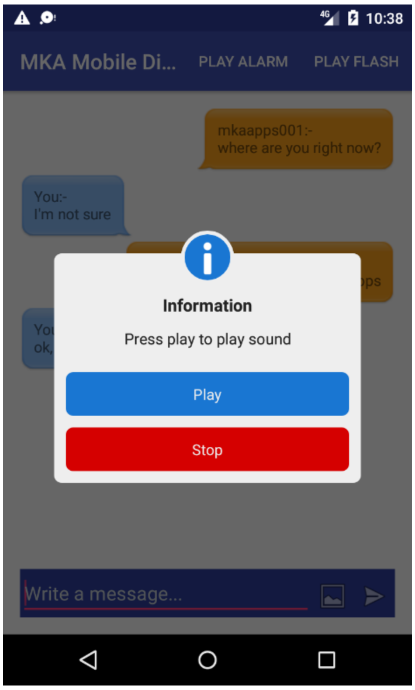
On the other hand, the MKA system also provides a text communication platform as in **Figure 53(B)**. This is important to make sure that MKA system is able to record all conversation for future analysis. Last but not least, victims who use MKA system can activate either flashlight or siren to alert helpers or rescuers to take them out from the dangerous area. A flashlight is useful when a victim is trapped in dark areas while siren is useful in any circumstances **(Figure 53(C))**. More details and snapshots are provided in **Appendix 2**.



(A) Notification



(B) Messaging



(C) Panic Alert Button

Figure 53: Notification, Messaging and Panic Alert Screen

4.6 Summary

In this chapter, I reviewed in detail the design, implementation and development of the system. The functionalities of the system were initially defined and the system design and modelling were carried out using Balsamiq Wireframes and Use Case Diagram. The system was implemented using Java and Firebase (Database). The snapshots of the finalised user interfaces of different functionalities and operations were then discussed.

Chapter 5 – Evaluation

5.1 Introduction

Based on the system and practical requirements, I conducted theoretical and empirical evaluations on all components of my design, including the formal framework as well as system design and its implementation, as appropriate. Based on web research, domain experts and scholars were identified in the fields of Emergency Response. In addition, based on targeted user groups, potential users of the system (e.g. targeted ages and smart phone skill levels) were also identified. Both were invited either verbally and/or by emails to participate in the evaluation process. An effort has been made to ensure that a balanced distribution of user testers is achieved. The analysis has been achieved in line with the research objectives stated in **Section 1.3**.

I conducted qualitative and quantitative evaluation methods to get more rigour evaluation results of this research. I used exploratory sequential mixed methods [121] where I began with a qualitative survey on MKA models and framework and explored the views of participants. I then analysed the data and the information used to build the system and conducted a second phase of the evaluation which is a quantitative-based analysis.

Several types of evaluation technique will be used for every task related to this research. MKA Framework, CTO and MKA system needed to be verified and evaluated in order to make sure this research is valid. This chapter presents a plan on how to evaluate this research project. It was divided into two parts:

1. Theoretical Evaluation
    - MKA System Requirement
    - MKA System Design Interface
    - Formal Framework
    - MKA System and Usability
2. Empirical Evaluation
    - System Implementation

Table 15 below shows the summary of users and experts participated in the each evaluation:

Table 15: Summary of Participants in the Evaluation Phase

Item	Category	Evaluation	Participant
1	Theoretical	MKA System Requirement 1. Completeness Evaluation 2. Correctness Evaluation	 5 5
2	Theoretical	MKA System Design Interface	14
3	Theoretical	Formal Framework	4
4	Theoretical	MKA System and Usability	11
5	Empirical	System Implementation	12

5.2 Theoretical Evaluation

5.2.1 Completeness of MKA Requirements Evaluation and Results

The completeness of the MKA System requirement was decided as one of the most important factors. This is because requirements will never be totally complete as long as MKA system is still in the research and must evolve to meet the changing needs of the research. Completeness testing is performed based on a set of tests followed by an interview. In this session, I used a testing method to validate all the requirements in **Table 14**. The system was tested several times with five potential users and the objectives are to verify all the requirements mention above (Please refer User Requirement Verification in **Appendix 3**). All the users are randomly selected from an intermediate skill level of Android users with no prior experience of using MKA system. The outcome is 100% of the users agreed that the functional requirements have completely realised. All the functions can be done, but only text and image messages have been tested by the users, as it is the same method that the phone uses to send image, video and audio files. The graph in **Figure 54** shows the evaluation result of the MKA System. Requirement 4 was not tested at the time of evaluation, because the implementation of using WiFi has not been completed. However, tests have been completed that the WiFi function of Android phones indeed can be used to send text and image messages.

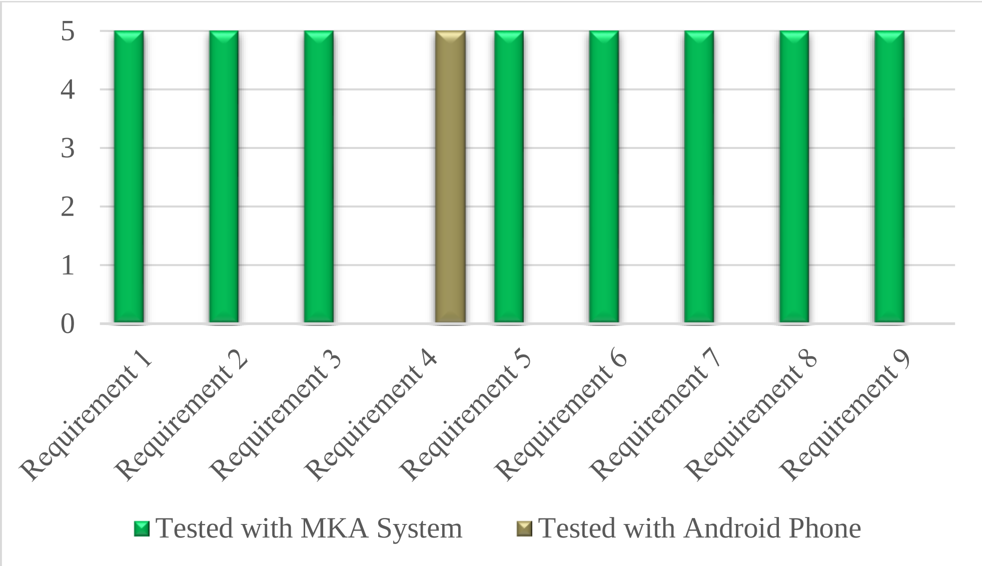


Figure 54: Completeness of MKA Requirements Evaluation of MKA System

5.2.2 Correctness of MKA System Functionality Evaluation and Results

In this section, I discussed the correctness of MKA system requirement in **Table 14**. Correctness is simply getting it right. Performing the correctness functionality testing is to define the level of operability, usefulness and easiness of using the system's functions. I used system testing as a method to evaluate the correctness of MKA system functionality. Additional five Android users were randomly selected to test the MKA system's functionalities. A set of test script of how to test the system functionalities has been given and its questions have been answered by the users (Please refer Test Script Verification in **Appendix 4**). After system testing, the testers have been asked about their opinion towards the correctness of the basic functionalities of the MKA system and whether the system meets the requirements. From the graph in **Figure 55** below it shows that 100% of users have agreed that all functional requirements have worked successfully in the MKA system.

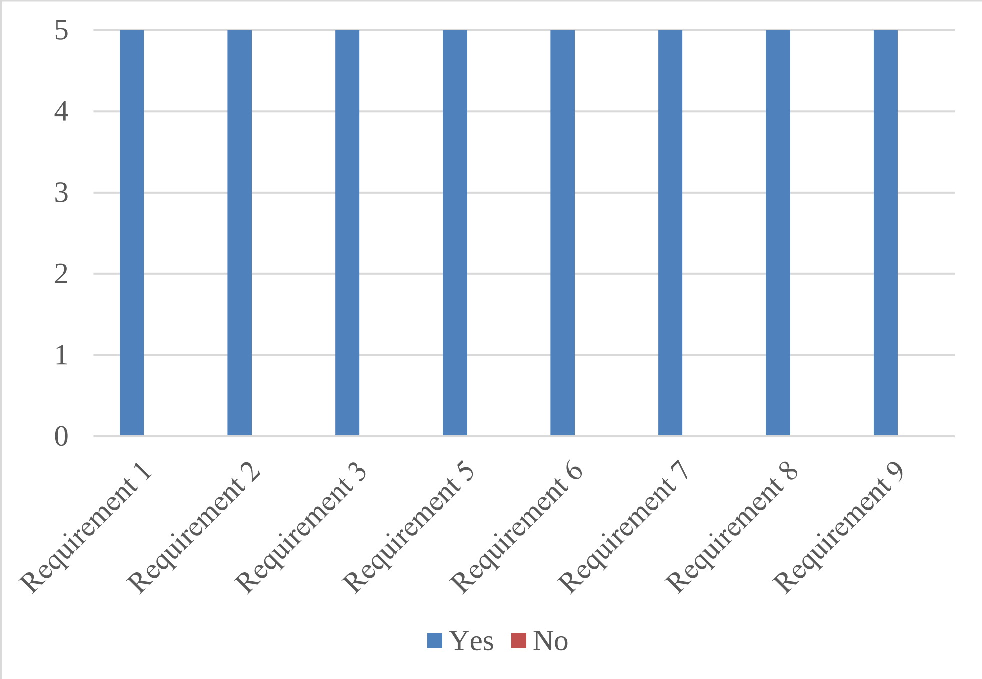


Figure 55: Correctness of MKA System Functionality Evaluation of MKA System

5.2.3 User Interface Design Survey Evaluation and Results

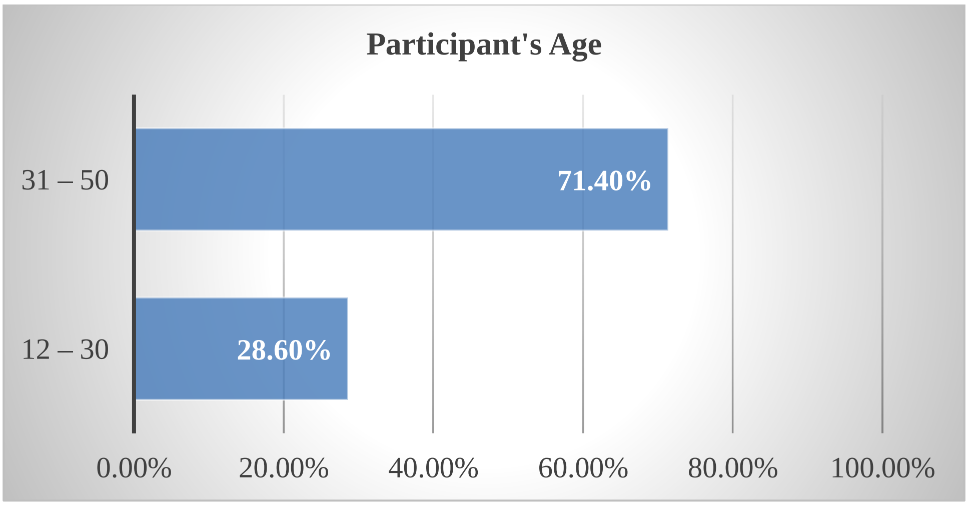
I have designed a User Interface using wireframes as mentioned in **Section 4.4**. Evaluate this design before the actual development of the system is very important, especially to understand the (potentially different) views of users such as those of different age categories. An interview was set-up with potential users, and they were grouped in four bands according to their ages, i.e. 6 to 11 (children), 12 to 30 (children and adult), 31 to 50 (adult) and more than 51 years old (matured adult).

A summary of evaluators' profiles is presented in **Table 16** and it is also presented in the graphs in **Figure 56(A) – (D)**. This survey was conducted with 14 respondents who have been randomly selected from users of Android smartphone. I believe the chosen participants represent the two corresponding age groups well (12 to 30 and 31 to 50), as they demonstrated the typical profile of "default/normal" mobile smartphone users, via their responses to my questionnaire. There are slightly more female participants (57.1%). Among all participants, half of them has experience of between 2 to 10 years of using any mobile apps on their smartphone and most of them are Android "normal" users where there only uses default/normal setting on their device without additional tailoring.

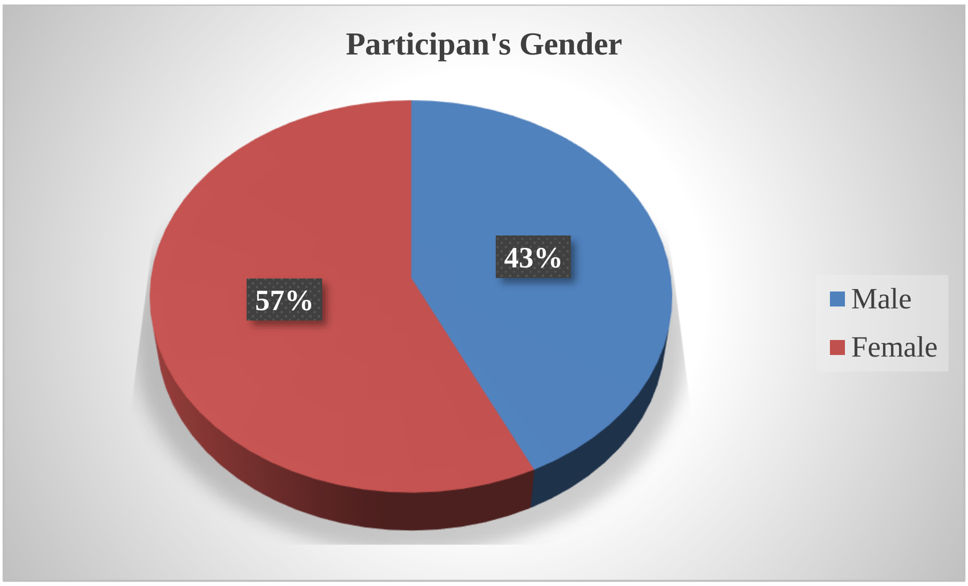
I also present the results of the verification of system requirements and interface design by the experts in **Section 5.2.4.6** and **Section 5.2.4.7**.

Table 16: Participant profile for User Interface Design Survey (**Appendix 1**)

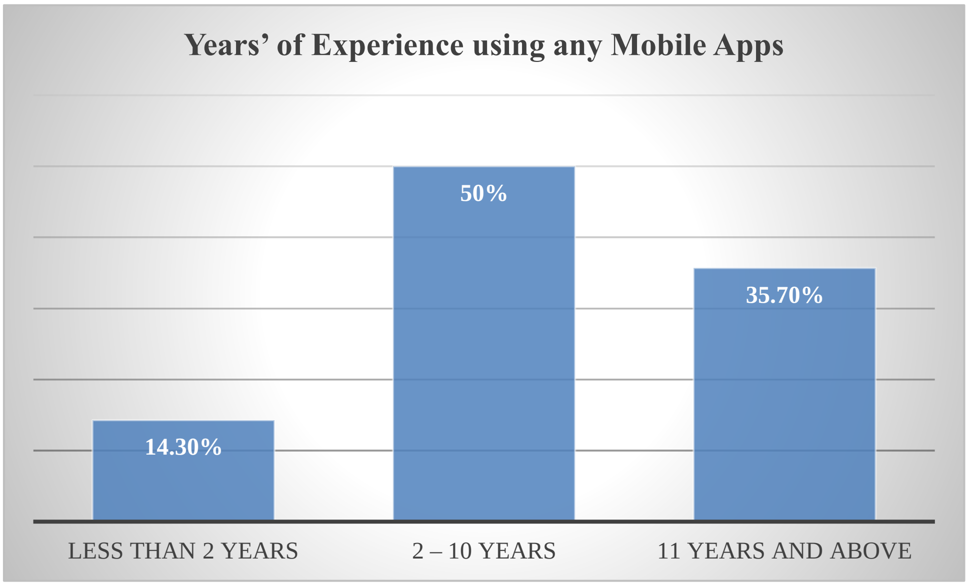
Category	Participant's Profile	Percentage	Frequency (N=14)
1	**Participant's Age**		
	• 12 – 30	28.6%	4
	• 31 – 50	71.4%	10
2	**Participant's Gender**		
	• Male	43%	6
	• Female	57%	8
3	**Years' of experience using any mobile apps using smartphone**		
	• Less than 2 years	14.3%	2
	• 2 – 10 years	50%	7
	• 11 years and above	35.7%	5
4	**Participant's level of use any mobile apps**		
	• Beginner (use basic setup)	21%	3
	• Normal (use normal setting)	50%	7
	• Expert (able to set advance setting)	29%	4



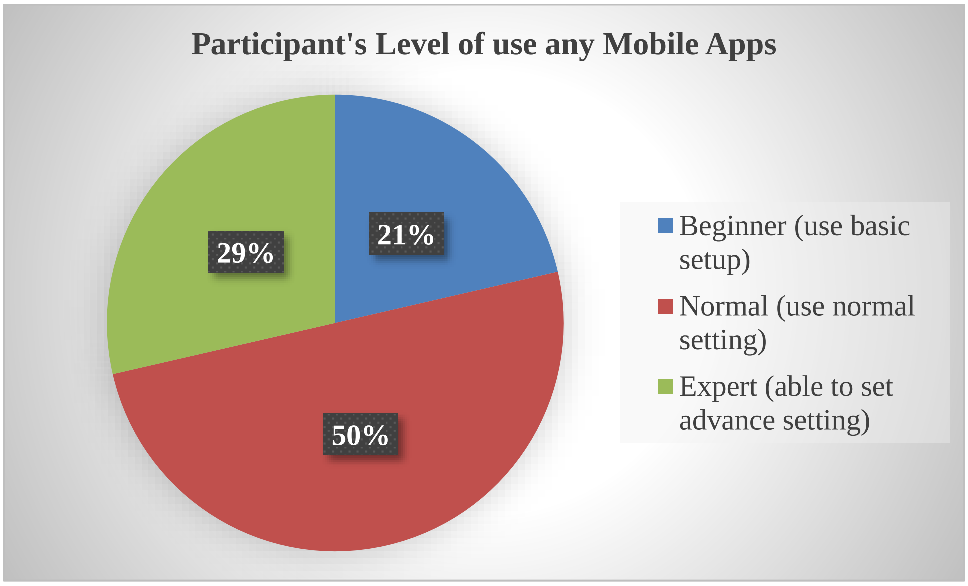
(A)


Participan's Gender
57%
43%
Male
Female

(B)


Years' of Experience using any Mobile Apps
14.30%
50%
35.70%
LESS THAN 2 YEARS
2 – 10 YEARS
11 YEARS AND ABOVE

(C)



(D)

Figure 56: Participant's Profile

Table 17 shows all participants' opinion towards the design of MKA system's user interfaces. These seven questions measure the system's usefulness and ease of use of the MKA system. The last and overall mean value of **4.3367** gives an average of all participants' opinions on all categories. It shows a strong consensus of all participants that they agree with MKA's user design. The results can be interpreted as "more than agreeable".

Table 17: Participant Opinion towards MKA User Interface Design (14 participants)

Question	Description	1 – Strongly Disagree	2 - Disagree	3 - Neither Agree nor Disagree	4 - Agree	5 - Strongly Agree	Mean
1	Feels like knew what to do and where to click	0	0	3	6	5	**4.1429**
2	Maps is useful for this apps	0	0	1	2	11	**4.7143**
3	Colours indicator in MKA apps is easier to understand	0	0	0	5	9	**4.6429**

Question	Description	**1 – Strongly Disagree**	2 - Disagree	3 - Neither Agree nor Disagree	4 - Agree	5 - Strongly Agree	Mean
4	Communication using text and picture	0	0	1	7	6	**4.3571**
5	PANIC BUTTON is useful in emergency situation	0	0	0	3	11	**4.7857**
6	MKA system application is user-friendly	0	0	3	11	0	**3.7857**
7	MKA system overall design	0	0	2	11	1	**3.9286**
							4.3367

5.2.4 Formal Framework Evaluation and Results

5.2.4.1 Introduction

The work reported in this section involves the evaluation of my formal framework with four experts in the emergency response area. All of them have relevant research or practical background in the field of natural disaster and/or emergency relief operations. They were selected using the snowball sampling method [122] or *simple random sampling*. Started from reviewing and searching potential experts on the Internet and finding those in a related conference, their contact information was listed based on their high profile and contributions in the emergency response field. Finally, three of them were selected from Taiwan and one is from Japan. Some of them have more than 5 years' Emergency Response practical experience, including assisting relief operations or evacuation and furthermore working in the control centre during the disaster. The advantages of using the snowball method is that it is quicker to find samples and it is also more cost-effective.

To verify my work, I set an interview using the same questions for them. The session begins with a short presentation of my work and then they would answer the questions. The questionnaires were divided into six sections to be verified by experts as below (Please refer to **Appendix 5**):

1. MKA Communication Framework
2. Communication and Tracking (CTO) Ontology
3. ER-Agent Communication Languages
4. ER-Agent Communication Protocol
5. MKA System Requirement
6. MKA System Mock-up Design

The results of each section were verified by the experts. The Likert scale has been used in my questionnaire to value the satisfaction with (1) Strongly disagree; (2) Disagree; (3) Neither agree nor disagree; (4) Agree; (5) Strongly agree. This method was used because it is the most widely used approach to scaling responses in survey research [123]. When responding to a Likert item, experts specified their level of agreement or disagreement on a symmetric agree-disagree scale for a series of statements. Thus, the range captures the intensity of their feelings for a given item. Means value with 3 and above in the diagram has been taken as the main component to show the satisfaction of the experts while means value with less than 3 showing that the expert does not agree with the component.

Additionally, the data in this section has been analysed using standard deviation (StDev) method as well. The purpose of using this method is to know how varied the data is (from the mean) and how the data may spread out within the domain. As a rule of thumb, a StDev >= 1 indicates relatively high variation. While a StDev < 1 is considered as low variation. This means the distribution with variation higher than 1 are considered as high variance; and with StDev lower than 1 is considered as a low variance (more uniform). In research, the values of StDev are not an argument either the value is good or not. It's because the value of StDev is just showing the indicator of how the data spread.

Overall ***Mean*** and **StDev** results shows that most of the experts are agreed and satisfied with my communication framework and the results of the analysis are shown in each section below:

5.2.4.2 MKA Communication Framework Verification and Results

Figure 57 shows the expert's satisfaction towards MKA Communication framework. **Table 18** shows a high level of approval and agreements with the design, with an overall average *mean* value of **4.4583**. While StDev for Evaluator1 = **0.51**, Evaluator2 = **0.49**, Evaluator3 = **0.45** and Evaluator4 = **0.52**. This finding indicates that all experts agree with all components in the MKA Communication Framework. However, through their text comments, experts were suggested modifying the structure of the diagram on the conceptual communication life cycle framework. Based on these comments, I have modified and finalised the framework diagram as presented in **Figure 9**, **Section 3.4.2.**

Table 18: Experts' Opinion towards MKA Communication Framework (**Appendix 5: Section 1**)

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

Evaluator	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Mean	Stdev
Evaluator 1	4	5	4	4	5	5	5	5	4	4	4	4	4.4167	0.51
Evaluator 2	5	5	5	5	5	5	5	5	4	4	4	4	4.6667	0.49
Evaluator 3	4	4	5	4	5	4	5	4	4	4	4	4	4.2500	0.45
Evaluator 4	5	5	5	4	5	4	5	4	4	5	4	4	4.5000	0.52
													4.4583	

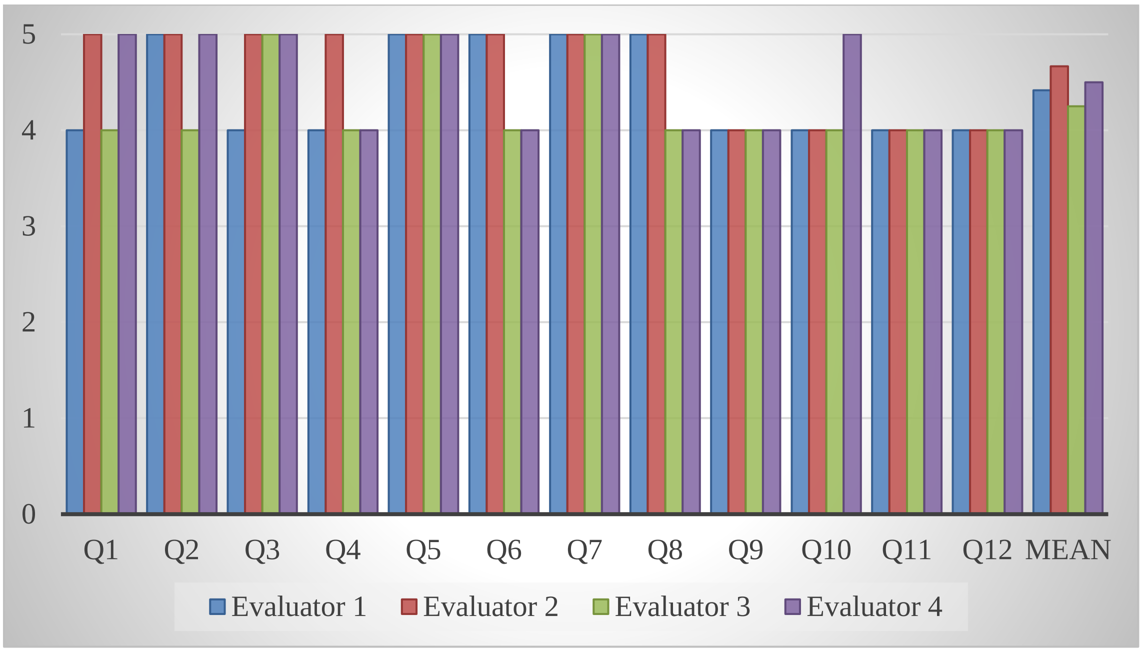


Figure 57: Results on the Satisfaction of MKA Communication Framework (Scale 1 - 5)

5.2.4.3 Communication and Tracking (CTO) Ontology Verification and Results

The experts were satisfied and agreed to the items in the CTO survey with a *mean* value of **3.7794** as shown in **Table 19**. **Figure 58** presents the graph of the CTO verification result by the experts. While StDev for Evaluator1 = **1.28**, Evaluator2 = **1.36**, Evaluator3 = **1.18** and Evaluator4 = **0.69**. Based on the findings, experts suggested some modifications to the components of Communication Tracking Ontology. The table below shows that the items Q5, Q8, Q11 and Q13 have some critical opinions - where not all experts think it is useful to include Resources (Q5), Event (Q11), Phase of Event (Q13) or Terrain (Q13) classes in ontology. For that reason, I have removed all of those items in my CTO for emergency response purposes. The finalised CTO was discussed and presented in **Section 3.5.2**

Table 19: Experts' Opinion towards Communication and Tracking Ontology (**Appendix 5: Section 2**)

1	**2**	**3**	**4**	**5**
Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

Evaluator	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Mean	Stdev
Evaluator 1	4	4	4	4	2	4	4	1	5	5	2	4	1	5	4	4	4	3.5882	1.28
Evaluator 2	4	5	5	4	2	5	5	2	4	4	1	4	1	5	4	4	4	3.7059	1.36
Evaluator 3	4	5	3	4	4	4	4	2	4	4	1	4	1	5	3	4	4	3.5294	1.18
Evaluator 4	5	4	4	4	5	3	4	4	5	5	3	5	4	5	4	5	4	4.2941	0.69
Mean																		3.7794	

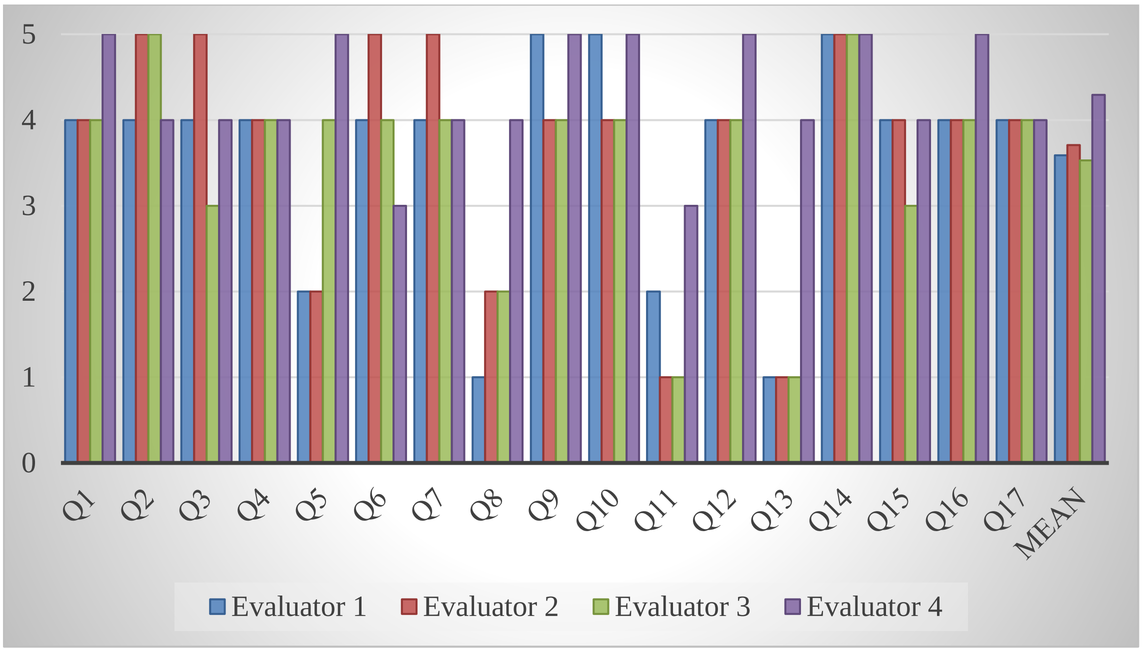


Figure 58: Results on the Satisfaction of CTO (Scale 1 - 5)

5.2.4.4 ER-Agent Communication Languages (ER-ACL) Verification and Results

Figure 59 represents the satisfaction graph of all the experts towards my ER-ACL. Items Q14 to Q17 show the experts did not agree on the items of event category, event type, the severity of event and impact of location as parameters in my ACL. Thus, I modified and removed all these items from my ER-ACL. Overall, the *Mean* of all categories for the result is **3.9519**, as shown in **Table 20** and the final ER-ACL was discussed in **Section 3.6.2.2.** While StDev for Evaluator1 = **1.29**, Evaluator2 = **1.20**, Evaluator3 = **1.31** and Evaluator4 = **0.93**. With the removal of item 14 to 17, this will boost the overall mean value to **4.35** which can be interpreted as “more than agreeable”.

Table 20: Experts’ Opinion towards ER-ACL (**Appendix 5: Section 3**)

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

Evaluator	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16	Q17	Q18	Q19	Q20	Q21	Q22	Q23	Q24	Q25	Q26	Mean	Stdev
Evaluator 1	4	4	5	5	4	4	4	4	4	4	5	4	3	1	1	1	1	4	3	4	3	4	5	5	4	5	3.6538	1.29
Evaluator 2	5	5	5	4	5	5	5	5	5	4	5	5	5	2	2	2	1	5	5	4	5	5	5	5	4	5	4.3462	1.20
Evaluator 3	5	5	5	4	3	5	5	4	4	4	5	3	4	1	1	1	2	4	5	3	3	3	4	5	4	5	3.7308	1.31
Evaluator 4	5	5	5	5	3	4	5	4	5	4	5	3	3	3	4	3	2	4	3	5	4	4	5	5	3	5	4.0769	0.93
Mean																											3.9519	

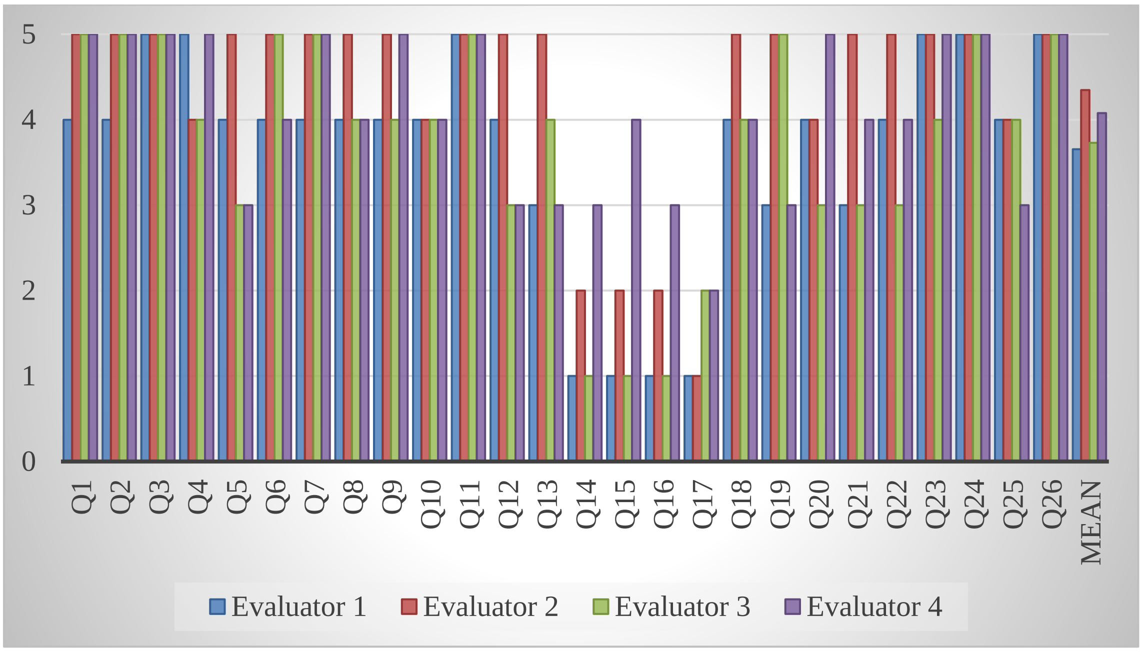


Figure 59: Results on the Satisfaction of ER-ACL (Scale 1 - 5)

5.2.4.5 ER-Agent Communication Protocol Verification and Results

Figure 60 shows that all experts agreed with my proposed emergency response scenarios are realistic with the *mean* value of **4.3269** (more than agreeable) in **Table 21**. StDev in this table shows that the Evaluator1 = **0.78**, Evaluator2 = **0.65**, Evaluator3 = **0.91** and Evaluator4 = **0.73**. In addition, some experts said that they have the first-hand experience where all networks were down, as people kept trying to make phone calls and sent a message to their families. As a result, a rich, structured messaging protocol will be most useful, as reported here. The finalised ER-ACP (Emergency Response Agent Communication Protocol) was discussed in **Section 3.6.3**.

Table 21: Experts' Opinion towards ER-ACP (**Appendix 5: Section 4**)

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

Evaluator	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Mean	Stdev
Evaluator 1	5	5	5	3	5	4	5	5	5	4	5	3	4	4.4615	0.78
Evaluator 2	5	5	4	4	5	5	3	5	5	5	5	5	4	4.6154	0.65
Evaluator 3	5	4	3	3	5	4	2	4	5	4	5	4	4	4.0000	0.91
Evaluator 4	4	4	5	3	5	4	4	5	5	3	5	4	4	4.2308	0.73
Mean														4.3269	

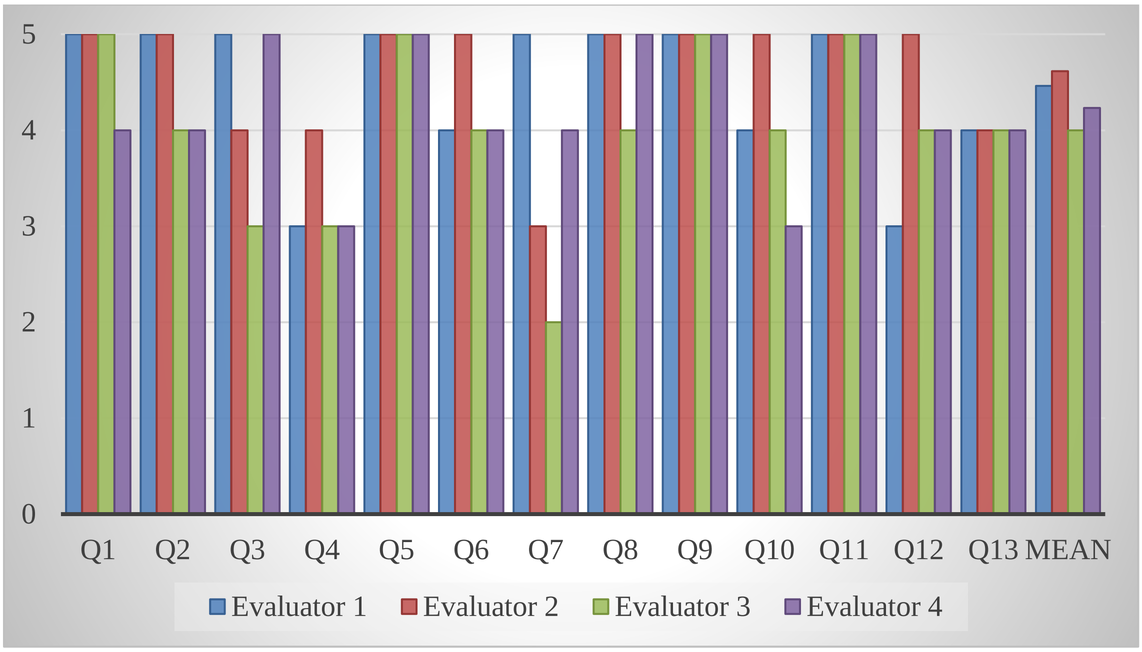


Figure 60: Results on the Satisfaction of ER-ACP (Scale 1 - 5)

5.2.4.6 Experts Review and Verification Results on MKA System Requirement and Design

For MKA system requirements, the views from experts are very important. A second system requirements evaluation has therefore been done with experts, although it has also been carried out with potential users. All of the experts agreed with all of the requirements that are present in **Table 22** are valid. **Figure 61** shows a graphic presentation of this information.

Table 22: Experts' Opinion towards MKA System Requirement and Design (**Appendix 5: Section 5**)

Evaluator	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Percentage
Evaluator 1	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	100.00
Evaluator 2	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	100.00
Evaluator 3	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	100.00
Evaluator 4	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	100.00

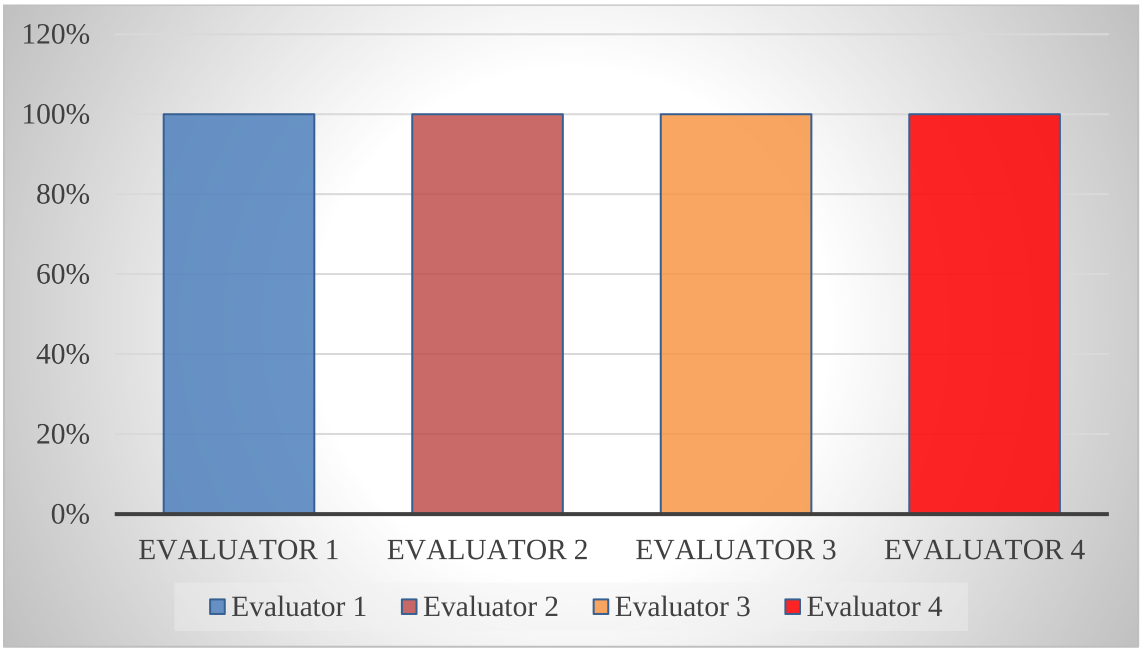


Figure 61: Results on the MKA System Requirement and Design by Experts

5.2.4.7 Experts Review and Verification on MKA System Mock-up Design

Another evaluation has been done with my mock-up user interface design. The experts' view on this issue is very important to make sure that the system I developed suites the proposed generic emergency response scenarios. *Mean* for the diagram in **Table 23** is **4.5000.** StDev in this evaluation shows the Evaluator1 = **0.00**, Evaluator2 = **0.33**, Evaluator3 = **0.50** and Evaluator4 = **0.44**. Based on the results, graph in **Figure 62** shows that the mock-up design is very good to be used by end-users. It was based on this evaluation result that the User Interfaces of MKA system was developed.

Table 23: Experts' Opinion towards MKA Mock-up Design (**Appendix 5: Section 6**)

1	2	3	4	5
Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree

Evaluator	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Mean	Stdev
Evaluator 1	4	4	4	4	4	4	4	4	4	4.0000	0.00
Evaluator 2	4	5	5	5	5	5	5	5	5	4.8889	0.33
Evaluator 3	5	4	5	4	4	4	5	4	4	4.3333	0.50
Evaluator 4	5	5	5	5	5	5	4	5	4	4.7778	0.44
Mean										**4.5000**	

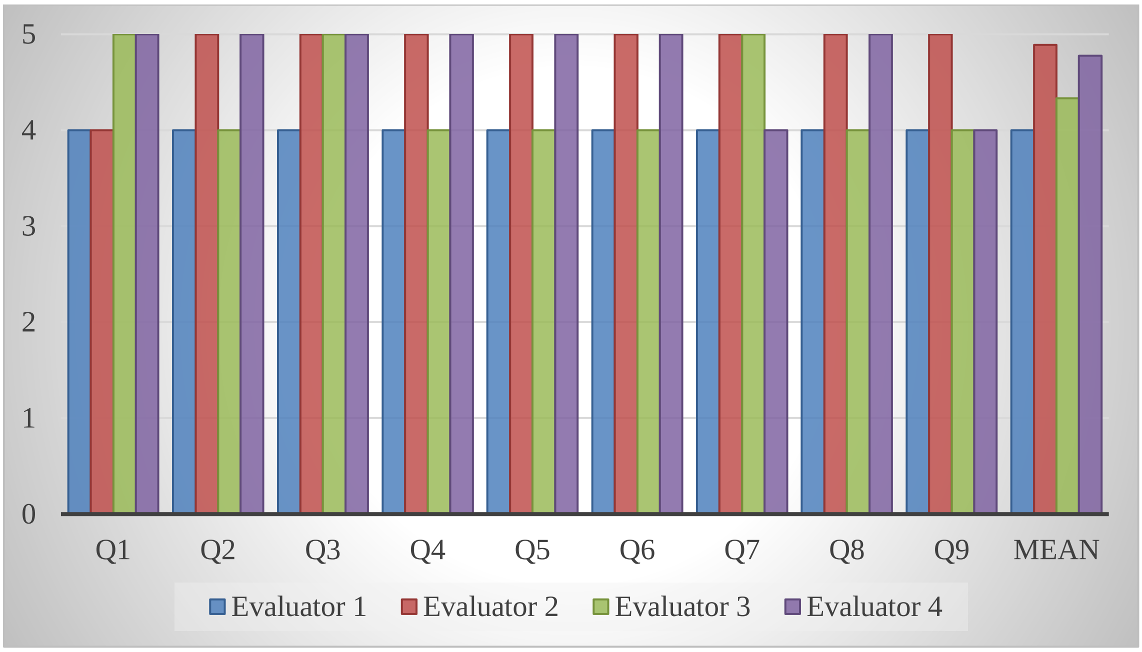


Figure 62: Results on the System Mockup Design (Scale 1 - 5) by Experts

5.2.5 Usability of Mobile Kit Disaster Assistant System Evaluation and Results

To evaluate the usability of MKA system, System Usability Scale (SUS) method [124] which was developed by [125] has been used to allow the usability system to be easily assessed. SUS is a standard measuring technique to evaluate a system or website. The usability testing with end users is one of the essential methods in usability evaluation [126]. SUS uses 10 questions for testers to response and at the end of the test, I convert the *Likert* scale answers from 0 - 4 to a new scale between 0-100 for each user. For the new scale, I multiply the *Likert* scale value by 2.5 to convert to the new range of 0 - 100 to get the new scores. This new score is not a percentage, it is a scaled SUS score value, where 68 is average - any score above 68 would be considered as above average (Acceptable) and anything below 68 is below average (Not Acceptable).

In this part of the evaluation, I invited 11 testers (samples) randomly selected from android users. Among them, 2 are classified as matured adults (more than 50 years old) and another 2 participants are children with age 10 and 12 years old. The rest of the participants are adults (between 31 to 49 years old). Minimum samples for SUS method is at least 5 samples according to [127]. In this session, participants were offered to installed MKA apps on their phones. After that, they used my pre-set user ID and passwords to allow speedier login. A very brief introduction to the MKA system has been given before they started to use and play with the system. After running through MKA apps, they answered the questionnaire in **Appendix 6**. Results and evaluation analysis using SUS method are shown in **Table 24**. From that, I found that 9 out 11 users or 81.82% of the participants had accepted MKA system with scores more than 68 as shown in **Figure 63** which shows that the system is usable for them. All adult testers found the system usable.

Table 24: MKA System Usability Scale (SUS) Scores (n = 11)

	Acceptable	**Not Acceptable**
Scores	68 and Above	Below 68

User	Age	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Score	Acceptable
User 1	Adult	2	1	4	4	3	4	4	4	3	4	**82.5**	Yes
User 2	Adult	3	0	4	3	4	3	4	3	3	3	**75**	Yes
User 3	Adult	3	2	3	3	3	3	3	3	2	4	**72.5**	Yes
User 4	Adult	3	3	3	3	3	3	2	2	3	3	**70**	Yes
User 5	Adult	0	2	4	4	4	4	3	4	4	4	**82.5**	Yes
User 6	Elderly	1	1	3	3	4	4	4	4	3	4	**77.5**	Yes
User 7	Adult	1	0	3	4	3	4	3	4	3	4	**72.5**	Yes
User 8	Elderly	0	2	2	2	3	3	3	3	3	3	**60**	No
User 9	Children	1	1	3	1	2	1	2	2	1	2	**40**	No
User 10	Adult	2	1	3	4	3	4	4	4	4	4	**82.5**	Yes
User 11	Children	3	1	4	3	3	3	4	4	3	3	**77.5**	Yes

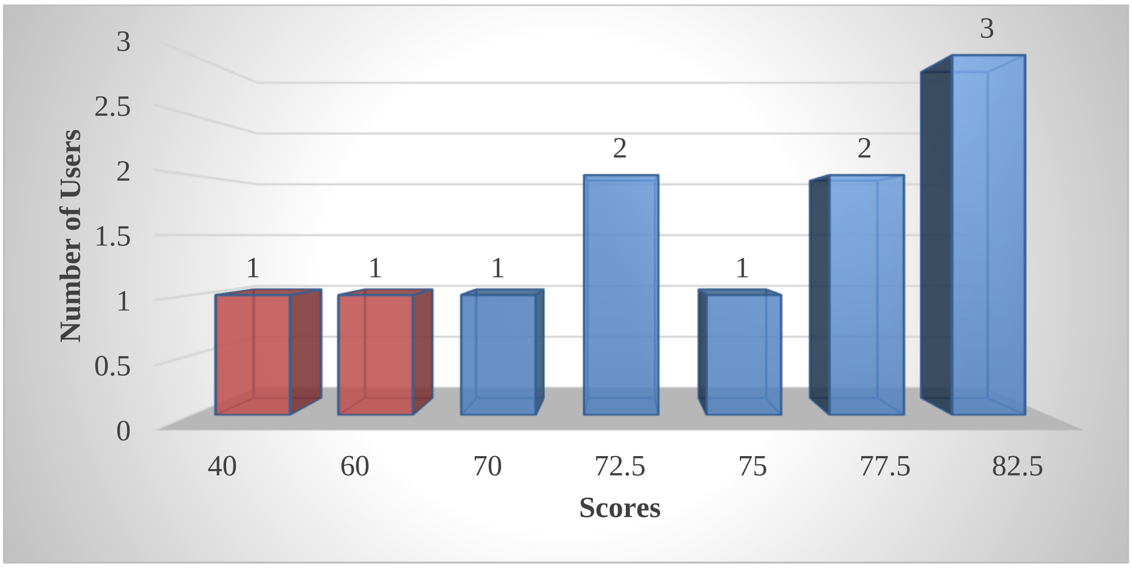


Figure 63: MKA System Usability Scale (SUS) Results by Number of Users (n = 11)

5.3 Empirical Evaluation

5.3.1 Background and Experiment Design

This section describes the empirical evaluations that have been carried out on the MKA mobile application running on Android mobile phones. All together 12 testers are involved. All of them already have an Android mobile phone. In preparation for the evaluation, MKA system was installed onto their own mobile phone.

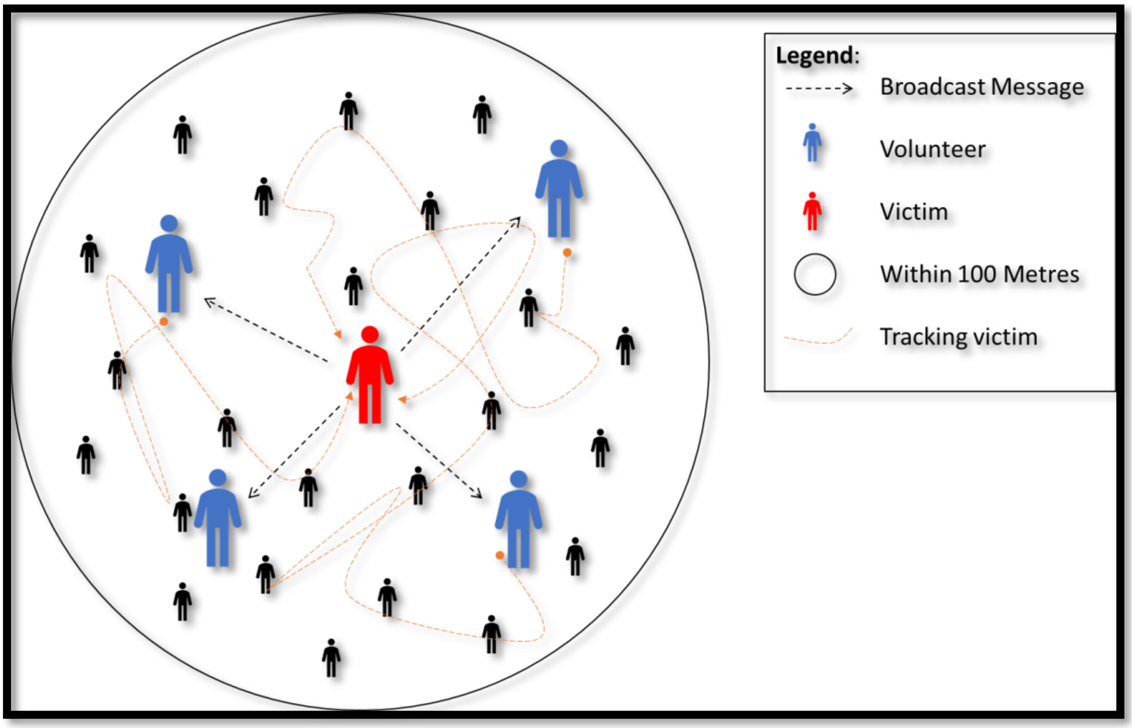


Figure 64: MKA System Broadcast Messaging Test Plan

Several realistic emergency response scenarios have been simulated involving real mobile users using the above mobile app. These experiments have been executed in a very busy, complex city centre. Similarly, the System Usability Scale will be used for gathering information and presenting evaluation results. The testers were given several tasks to be completed within a short-limited time. The purpose of this evaluation is to find out the usability of the mobile app in that how practical or useful it may assist communication to help relay information, forge collaboration, seek and provide help and recover the victim.

The evaluation is divided into multiple sessions. Each session started with the briefing of the experiment, the installation of MKA system and giving out instructions on how to use the system. Each person is given the role of either *victim*, *volunteer*, *family/friends* or *medical worker*. When the testing session begins, they have been asked to go around in the testing location area (within 100 metres) - in my case, I do the test in the Edinburgh city centre. The session ends when a *volunteer, family* or *medical worker* track, find, helps (bring first aid) and/or “rescue” the *victim* by using the MKA system only.

In each session, one of the group members randomly asked to act as a victim who will hide among the crowd. For the first session, the scenario as depicted in **Figure 64** has been simulate where the other four participants are to be *volunteers*. This scenario simulates the most common situation that an earthquake victim may encounter – to ask help from anyone near them, as such people are typically the first responders who offer help because they are at the location.

To begin with, all participants were asked to scatter around in the test location and run the MKA mobile system. After everyone is in position, the victim was to broadcast an *ask-help* message to all of his nearby rescuers, all volunteers will receive the same message from the victim. The first *volunteers* (who is not pre-determined) that decided to accept the ask-help request will get the rescue job, and the other volunteers will see on their MKA mobile app that this ask-help message has been taken/dealt with. The “winning” volunteer can then communicate with the victim through the messaging component in MKA system to try to locate him.

From their mobile apps, everyone can see where everyone else is via the Google Map this is integrated within the MKA mobile app. However, the rescuer can choose and see the location of the specific victim that he had promised to help, by pressing the ask-help notification from the Victim. The left image **Figure 65** shows a list of notification messages on the helper’s mobile phone. This is a very important function of the MKA system that the MKA mobile app does not need to be opened at all times but can still receive ask-help messages from victims.

However, the helper can learn more about the victim by interacting with the notification messages. As in **Figure 65**, the top two notifications are MKA messages.

To find out the location of the victim, the rescuer can decide to press on the 1st notification to see the location of the victim on Google Map. He/she can also use the Google Map's navigation system to find the victim.

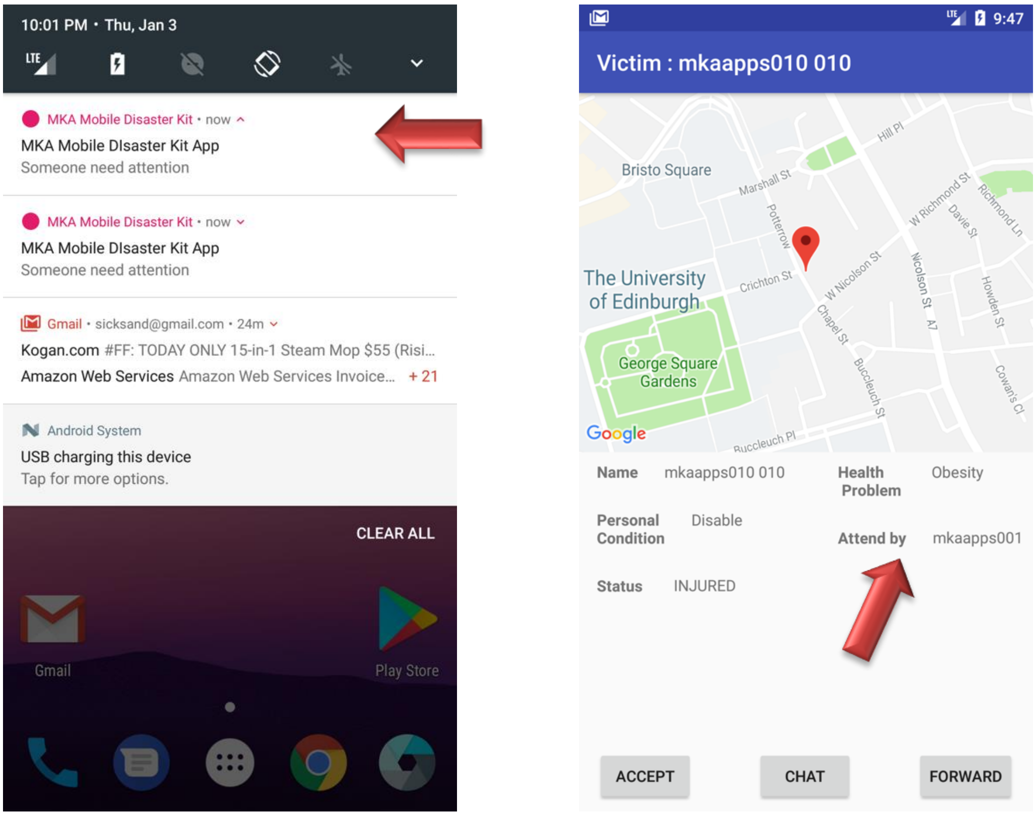


Figure 65: Left: notification screen on the helper mobile phone; Right: location of the Victim shown on the helpers' MKA mobile app screen using Google Map

In the second scenario, I created a similar simulation as in **Figure 66**, but in this case, six volunteers and one victim participants participated. Similarly, it started with the victim broadcasting ask-help message to all nearby volunteers. Instead of asking all volunteers to accept the help message, I randomly asked two volunteers to refuse the ask-help message but forward it to other volunteers (this is shown in the purple dashed line). I assume in this scenario, two of the volunteers who cannot help the victim because they are busy helping other victims. When a volunteer accepts an ask-help message, the volunteer will try to track and find the victim (searching routes are shown as red dash lines). A pop-up message will appear on the volunteer's screen when he/she has successfully forwarded the victim's original message to another/other volunteers

(**Figure 67**). Volunteers and victims can communicate using chat function as provided in the MKA system.

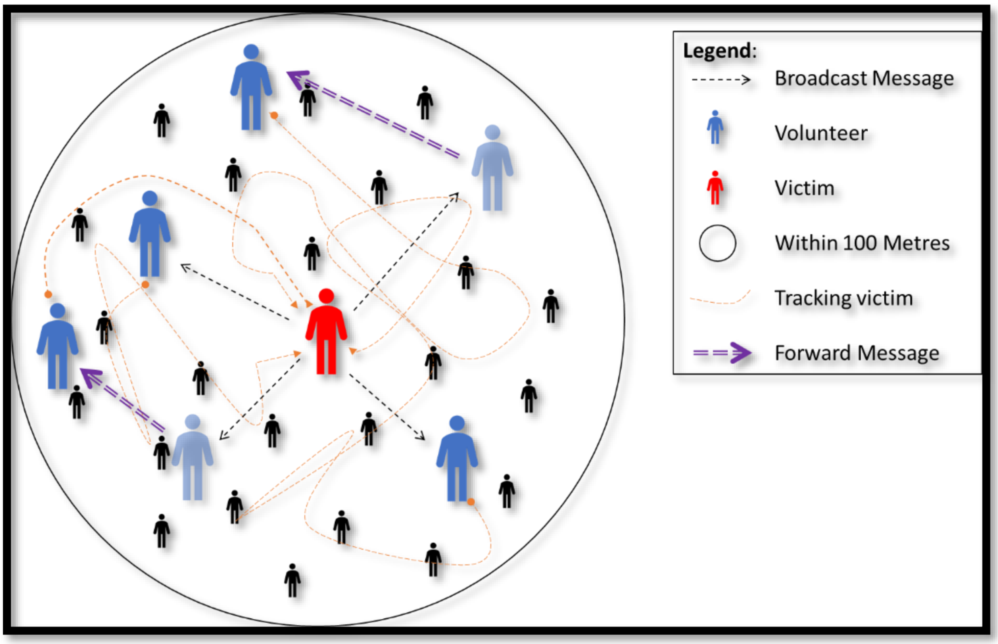


Figure 66: MKA System Forwarding Messaging Test Plan

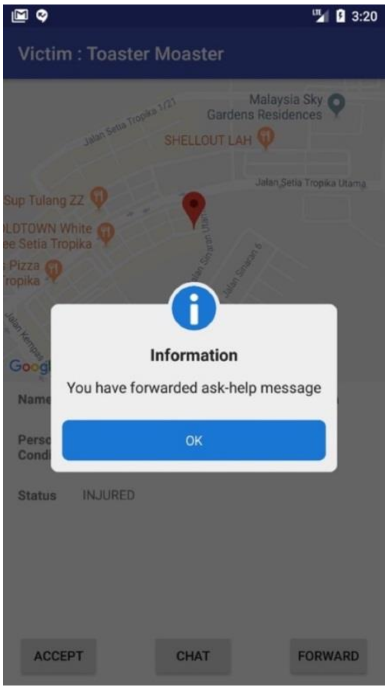


Figure 67: Pop-up Message on Volunteer Screen: To confirm that an ask-help has been forwarded

During the last session, I created a scenario in **Figure 68** where it involved a victim family member who is able to see the victim's status, but he/she is not assisted by any volunteers. I assume the family member is away from the victim's location and he/she, therefore, cannot help personally or immediately. In this scenario, the victim started it with sending a personal custom message to his/her family, this family member will forward the message to volunteers nearby the victim, as in **Figure 69**. The family members can see and identify all volunteers from the Google map made available via the MKA system. This family member can monitor if any volunteers had accepted his/her request from his/her own MKA screen; and can forward the message to other volunteers, if the victim is still not assisted by anyone after a while.

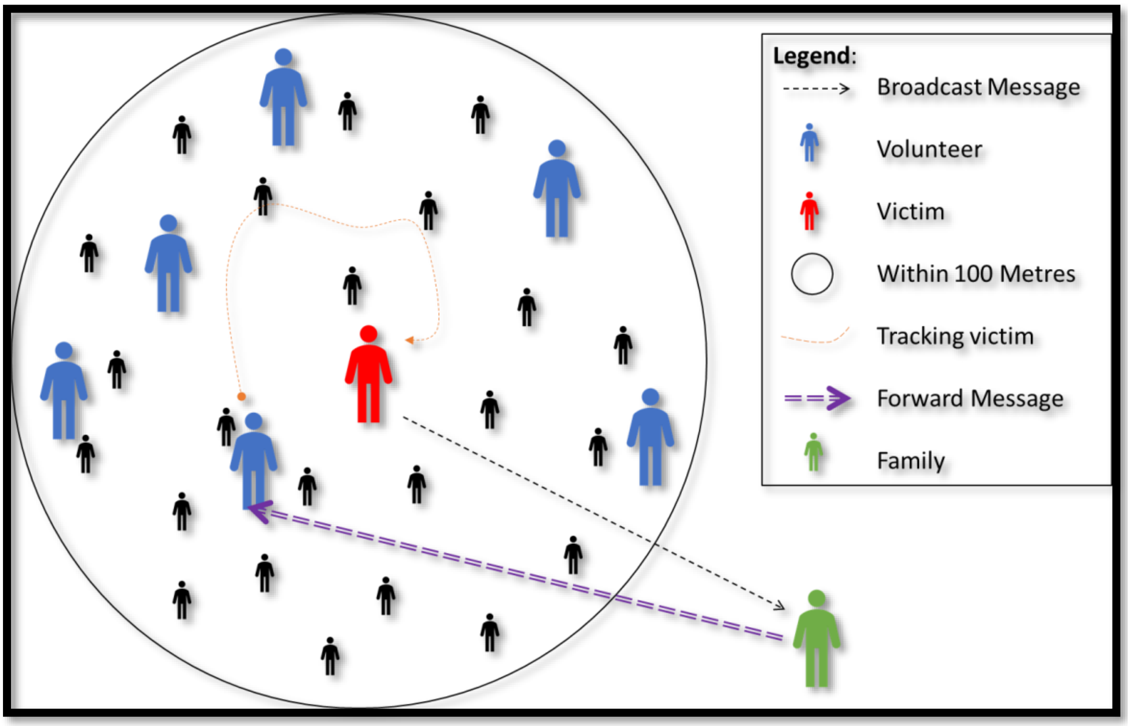


Figure 68: MKA System Direct Messaging and Forwarding Test Plan

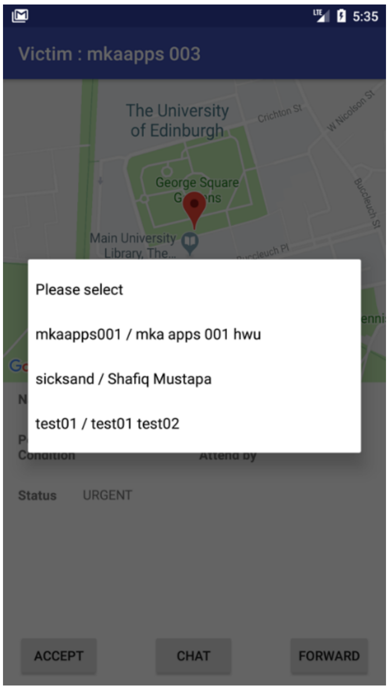


Figure 69: List of Volunteer Nearby the Victim

5.3.2 System Implementation and Results

After each session, I asked the participants to complete the SUS questionnaire to analyse the results. The test was completed with 12 participants in total, in which 7 of them are adults, 2 matured adults and 3 children/young adults (age 9, 12 and 14) to evaluate MKA system usability through the implementation of the system as described in **Section 5.3.1**. The data was analysed using the same calculation method described in **Section 5.2.5**. The analysis table results shown as in **Table 25** and from the table, I found that 83.33% (10 out of 12) shows that MKA system was acceptable as in **Figure 70**.

Table 25: Empirical Evaluation for MKA System Usability Scale (SUS) Scores (n = 12)

	Acceptable	**Not Acceptable**
Scores	68 and Above	Below 68

User	Age	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Score	Acceptable
User 1	Adult	4	0	3	4	4	4	3	4	3	4	**82.5**	Yes
User 2	Adult	4	1	4	4	4	2	4	4	4	3	**85**	Yes
User 3	Adult	4	1	4	3	3	3	4	2	3	3	**75**	Yes
User 4	Elderly	3	0	3	3	3	4	3	3	2	3	**67.5**	No
User 5	Adult	4	1	4	3	4	4	3	3	3	4	**82.5**	Yes
User 6	Elderly	2	0	4	2	4	3	4	4	4	3	**75**	Yes
User 7	Children	2	1	4	1	3	4	4	3	4	4	**75**	Yes
User 8	Adult	3	0	4	4	4	4	3	2	4	4	**80**	Yes
User 9	Children	3	1	2	2	4	2	3	4	2	3	**65**	No
User 10	Adult	2	2	2	3	4	4	3	4	3	2	**72.5**	Yes
User 11	Adult	3	2	4	4	3	3	4	3	4	3	**82.5**	Yes
User12	Children	1	2	3	4	4	4	3	4	3	1	**72.5**	Yes

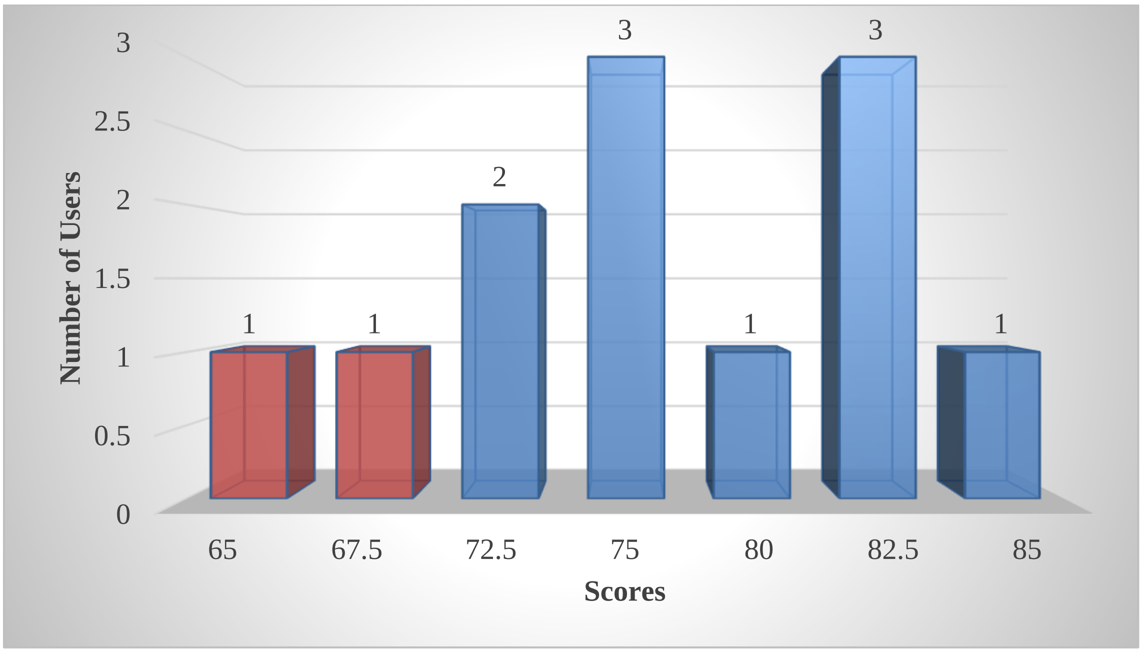


Figure 70: Empirical Evaluation Result for MKA System Usability Scale (SUS) by Number of Users (n = 12)

Comparing with system usability test between graph in **Figure 63** and **Figure 70**, it showed that people who had previously played around with MKA system had given 81.82% rate as acceptable; whereas others who used the system with my implementation strategy and simulation planning, the result has increased almost 2% to 83.33%. Therefore, believe that prior hands-on experiences of using MKA system will boast user abilities in tracking and communicating using the MKA system.

5.4 Summary

The objective of this chapter is to evaluate the completeness, correctness, user interface design and the MKA formal framework as well as system usability of the MKA system. A mixture of evaluation methodology has been used to evaluate my research. I collected user data to analyse the completeness and correctness of my system requirements and discussed findings. For user interface design evaluation, the profile of the respondents was presented before discussing the data collected and then the results were interpreted. On the last evaluation, I used the SUS evaluation method to evaluate MKA system's acceptability from participants. In the next chapter, the work presented in this thesis is recapitulated to summarize the research problem, issues and the proposed solution.

Chapter 6 – Conclusion and Future Work

6.1 Introduction

This chapter presents the work that has been undertaken and documented to address the identified research issues in the thesis. The different contributions made to the literature through this thesis are also presented. This was followed by a brief description of future work that may be considered to extend this study.

6.2 Main Claims of Research

Most of the existing research in the field of communication, tracking and rescue for emergency response in a large-scale disaster is focused on providing support for organisations. It is very little to none work that focuses on providing tools for personal and personalisable use; and more importantly to utilise opportunistic resources, such as volunteers from the general public that are already located nearby the disaster struck area and are ready to help. Unfortunately, such opportunistic and un-organised resources are often the first responders for any natural disasters. This research, therefore, wishes to bridge this gap by providing relevant support.

In this research, the emergency response problem has been reframed as an agent-based problem, in that all human are seen as agents and the mobile apps and systems are seen as the representation of the human using it. A few new innovations have been created. A formal yet practical framework has been created that includes the following components in **Figure 71** below:

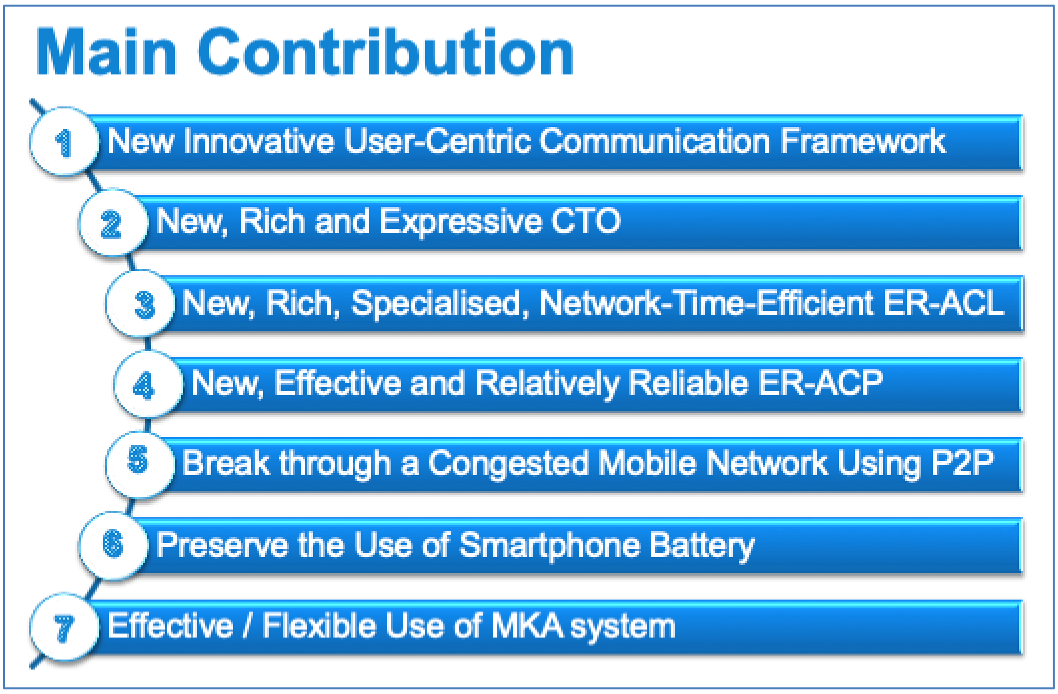


Figure 71: Research Main Contribution

- A new formal telecommunication framework for emergency response for a personalised mobile system. A user centric based which include background knowledge / information of the user such as medical conditions, their doctors, nurses, families and etc. It provides an underlying framework for mobile system communication, Inc. mobile phone communication via mobile and ad-hoc (WiFi) networks;
- A new emergency response ontology that no other similar ontologies existed based on my best knowledge. It was built based on concepts defined and described in many Emergency Response handbooks, guidelines and other relevant standards. A rich ontology with multimodal method such as voice, image, videos and text. Its purpose is to store relevant background information that is ready to be used to support Emergency Response communication as disasters strike;
- A new formal emergency response agent communication language (ER-ACL) that vastly extends the original standard of FIPA agent communication language. It proposed many new emergency responses related communication performative while allows personalised messages, to enable a more structural, meaningful and speedy communication (instead of normal voice conversation

that causes network congestion during disasters). To make use of smartphone's capabilities, it also supports non-text messages, including images, voice and video clips that were not included in FIPA.

- A new formal emergency response agent communication protocol (ER-ACP) to enable structural and systematic communication to ensure communication qualities (e.g. pre-determined communication sequences to ensure meaningful conversations; prevent the loss of communication threads by using 2-way and 3-way handshaking telecommunication protocols).
- An efficient system with the capability of auto smart randomly sending a pre-text or custom message to nearby volunteers when necessary can preserve the usage of the smartphone battery.
- An effective and flexible system that can be used for small or large scale emergency response scenario.

Furthermore, to demonstrate the usability of the above formal framework, a new personalisable MKA mobile communication system was implemented in Android smartphones and it has been evaluated rigorously - its design (including the above formal framework) had been evaluated by experts, and the built system tested by potential users (including the younger and older generations). These evaluations have achieved very positive results and both of the theoretical and empirical approaches have been deployed. The theoretical approach had involved both of the experts and potential users. The empirical approach had utilised potential users to simulate expert-approved realistic emergency responses scenarios using Android smartphones.

6.3 Summary and Further Discussion

In the formal framework for the agent-based personal mobile system, three main components have been proposed in this research, i.e. a communication framework; an ontology for communication and tracking; and emergency response agent communication languages and the protocol.

All main components have been discussed in **Chapter 3** and the sub-section. My communication framework tackles four main roles in communication in an emergency situation. The main role such as victim, family & friends, rescuer & public volunteer and medical & social careers are very important in communication and tracking people in needs. The victim can communicate and retains the right to choose when, how and what personal information will be shared, or not shared, and what information to be shared with whom. My understanding is that in the event of an emergency situation, not all victims want to share everything with all of the rescuers. In a small-scale emergency situation, for example, the victim may wish to share and communicate with their family only and not to the rescuers. This approach of protecting private information makes my framework suited to large, normal or small-scale emergency response situations. The communication framework I developed has answered the first research questions in **Section 1.5** where my framework is useful for communication purposes and it has been agreed by experts.

In **section 3.5**, CTO ontology was discussed in detail. I developed the new ontology to suit communication/tracking for a mobile smartphone using a seven-step approach. I found that many ontologies have existed and used for different objectives and purposes, but there is no one ontology that is suitable to be used for communication and tracking people in the domain of emergency response, especially for a mobile smartphone. CTO has been evaluated and agreed by experts that it's useful particularly in integrating heterogeneous data and to support communication and tracking people using a mobile device. This idea has been viewed and response by experts and it answered my point number two, three and four in research questions.

Agent communication languages and the particular protocol was discussed in **Section 3.6**. I created a new ER-ACL by gathering relevant information from multiple resources as a method for exchanged information between two or more agents. I enhanced and extended existing FIPA-ACL with ten new performatives and fifteen new parameters in ER-ACL. I applied ER-ACL using ER-ACP to suit emergency response situations, such as scenarios of broadcasting ask-help messages and forward ask-help message to another volunteer. All of the new performatives and parameters in ER-ACL and ER-ACP have been evaluated by experts. From their feedback, I then modified a few items in ER-ACL and the final results showed that they are satisfied with my new ER-ACL. One important part is that I applied the standard three-way handshake telecommunication protocols, where appropriate, in my communication model to ensure that the information transmitted has arrived safely at its destination. This is especially important for complex scenarios as discussed in **Section 3.6.3.2**.

In order to show that this theoretical formal framework provides a sound foundation for communication in emergency scenarios, **Chapter 4** presents the design and implementation of the MKA system. It also presents a validation process using the system usability scale (SUS) with testers who are within the targeted user groups. There are many mobile applications exist in real life but to the best of my knowledge, none of them has a disaster or emergency response knowledge base or ontology to provide contextual knowledge - which would be very useful in the event of an emergency to support speedy and precise communication via using clearly defined and understood vocabularies. Therefore, I developed my MKA system suited to a knowledge base that follows the newly and specifically defined CTO ontology. Starting with system requirements and design, I then created a set of screen design before the description of the implemented system. The system was run and tested a few times before it was tested by participants of targeted user groups. I evaluated all segments of the system by different participants and the results are very positive, as shown from **Section 5.2.1** to **Section 5.2.5.**

Chapter 5 provided a thorough discussion of the verification and validation processes in two sections: **Section 5.2** explains the theoretical evaluation and **Section 5.3** the empirical evaluation. The system was tested thoroughly by mobile smartphone users for helping them to communicate and track down other people in needs. The overall results were very positive and it showed that my system is indeed usable and useful.

These use-cases showed that the mobile system approach taken in this thesis allows us to be far more flexible and precise about information sharing between agents on the subjects of who (to communicate), where (the communication is originated from), what (to communicate), when (to communicate) and why (to communicate). As more information is added to the knowledge base, the possibilities for the system to use and allow for some exciting and unforeseen data to emerge are increased. Overall, this thesis shows that my formal agent-based personalised mobile system to support emergency response is important and beneficial for:

- Effective communication that is necessary to save lives in emergency response
- Mobile devices are suitable for personalising communication and used as a coordination medium
- Enable an automated and personalised mobile communication system by creating a formal framework that includes the following components:
  - A communication framework for personal mobile system
  - An emergency response ontology designed to support Emergency Response scenarios
  - A formal emergency response agent communication language (ER-ACL)
  - A formal emergency response agent communication protocol (ER-ACP)

With this research, I hope that not only people in large scale of emergency response scenarios such as earthquake disasters can benefit from this formal framework and mobile system, but it can also help people in emergency in general, such as in the case of mountain climbers who were saved while stranded in the Swiss Alps in 2003 [128] and a 59-year old man who had fallen whilst climbing on Crib Goch in Snowdonia who had injured his chest and legs [129]. The other tragedy is when a student from Ohio, the USA who called 2 times to 911 but was founded dead hours later because the police could not find the exact location where he trapped in the school parking lot [130]. The MKA mobile system should be helpful in such situations, especially for the last case above.

6.4 Recommendation and Future Work

In this research, I discovered that this work is only at the beginning and more work can be done to help emergency response using mobile devices, especially at a user-centric, personal level. Throughout the thesis, I highlighted a number of possible future directions. The most important ones now summarise.

Extending the CTO - My evaluation led me to identify interesting aspects of the latest sensor technology information that are related to disaster and emergency response and may be useful to be recorded. As such work is outside of the project scope, the CTO does not currently capture them. It, therefore, remains future work for other interested parties to extend the CTO and tackle these different aspects, including sending partial information of an exact location and the environment that it is located within.

Web-based Data Visualisation - Apart from what the MKA mobile-based system can present, there is a lack of a centralised system that may provide an overview visualisation of all emergency response information that may be made available on the web. Future work includes the creation of information visualisers, allowing everyone involved to map particular tasks to information. This centralised based overview, however, may cause other problems, such as trust and privacy issues, as personal data may be revealed which therefore would require further research to provide proper protections and boundaries – just as they have been very carefully considered and protected in this research.

Prioritise Messages – With the limitation of network bandwidth/usage after the large scale disaster such as P2P, WiFi and mobile network, the existing MKA system can be properly designed and improves in terms of to prioritise the message sending. Categorised the message can be part of the enhancement of the system where it can automatically control what message content can be transmitted based on available bandwidth e.g. when P2P network is used, only text message may be sent to the nearby volunteers. While another network is available, the system would allow pictures, voices or video messages to be transmitted.

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Appendix 1

Survey on Pre-Development of Mobile Application Design, Features and Function

Hello,

We are doing research project for emergency response in large-scale disaster and will develop a mobile app named Mobile-Kit Disaster Assistant (MKA) for the earthquake. You are invited to participate in this survey to improve our design, features and functionality of MKA apps.

Your participation in this study is entirely voluntary. There are no foreseeable risks associated with this project. However, if you feel uncomfortable answering any questions, you can withdraw from the survey at any point. It is important for us to learn your opinions.

Your survey responses will be strictly confidential, and data from this research will be reported only in the aggregate. Your information will be coded and will remain confidential. If you have questions at any time about the survey or the procedures, you may contact me by email at mh42@hw.ac.uk.

Thank you very much for your time and support. Let's get started!

* Required

Your Personal Profile

1. **1. Please choose your age range listed below** *

   Mark only one oval.

   - 6 - 11 years
   - 12 - 30 years
   - 31 - 50 years
   - 51 years and above

2. **2. Please choose your gender** *

   Mark only one oval.

   - Male
   - Female

3. **3. How long you used any mobile application in your smart phone?** *

   Mark only one oval.

   - less then 2 years
   - 2 - 10 years
   - 11 years and above

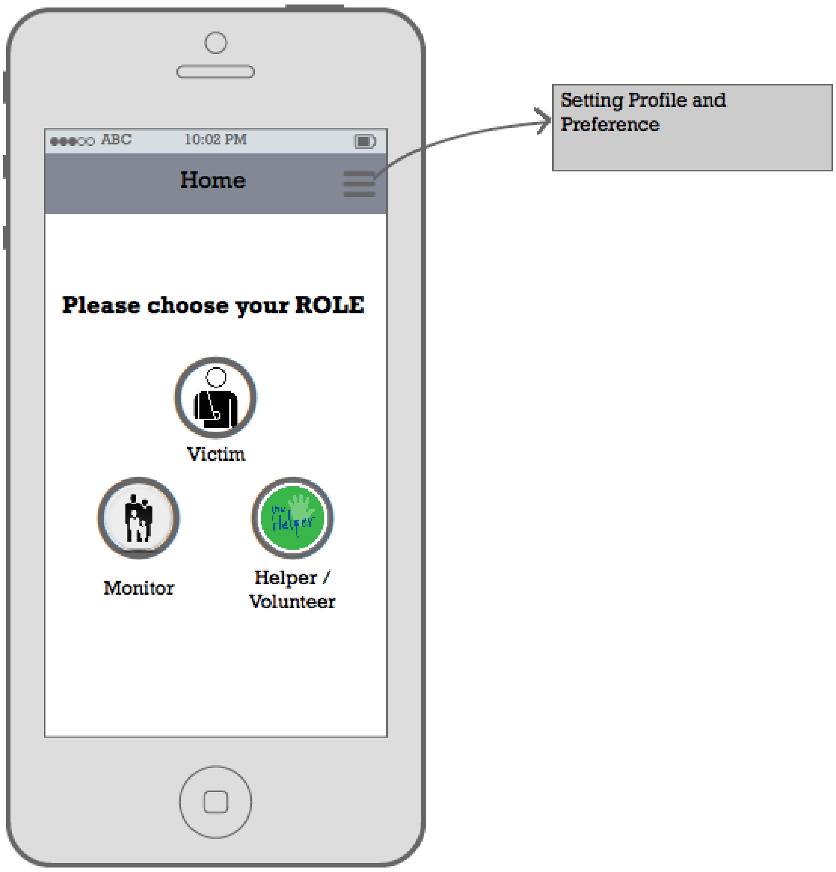
4. **4. Please categorised yourself in using any mobile application?** *
Mark only one oval.

- Beginner (use basic setup)
- Normal User (use normal setting)
- Expert User (able to setting more features)

Your opinion towards MKA Mobile App System

5. **5. Did you always feel like you knew what to do and where to click?** *

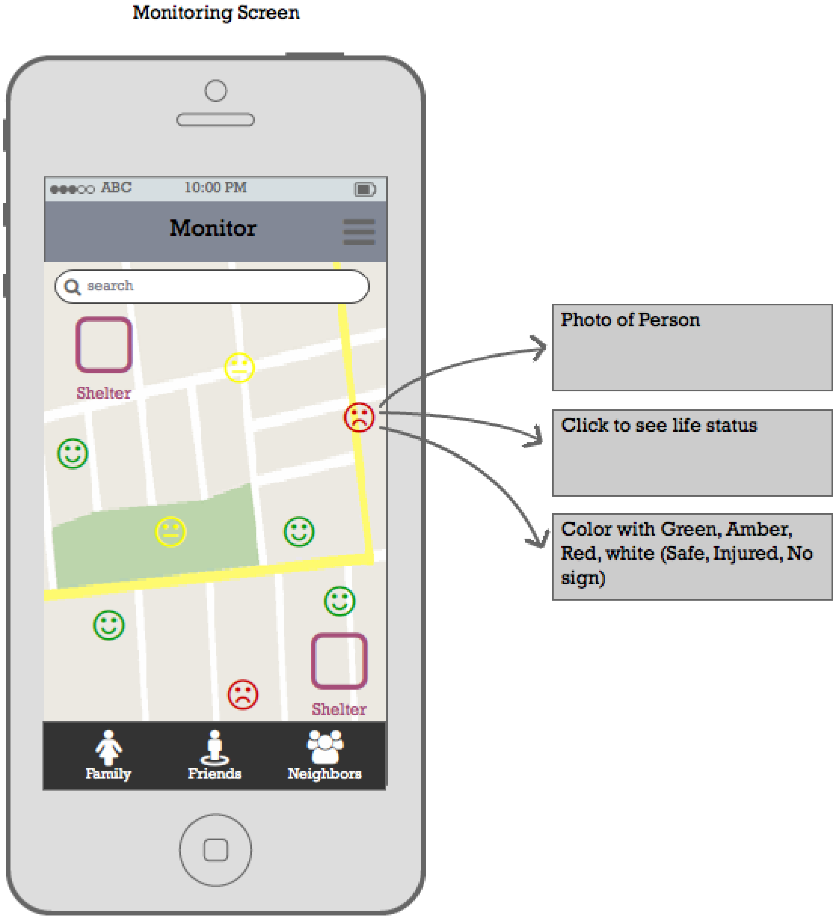
Home Screen



Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

6. **6. Do you think that maps function is useful for this apps?** *



Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	⬭	⬭	⬭	⬭	⬭	Strongly Agree

7. **7. Do you think that the three colours indication in this apps is easier to understand? (green, amber, red)** *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	⬭	⬭	⬭	⬭	⬭	Strongly Agree

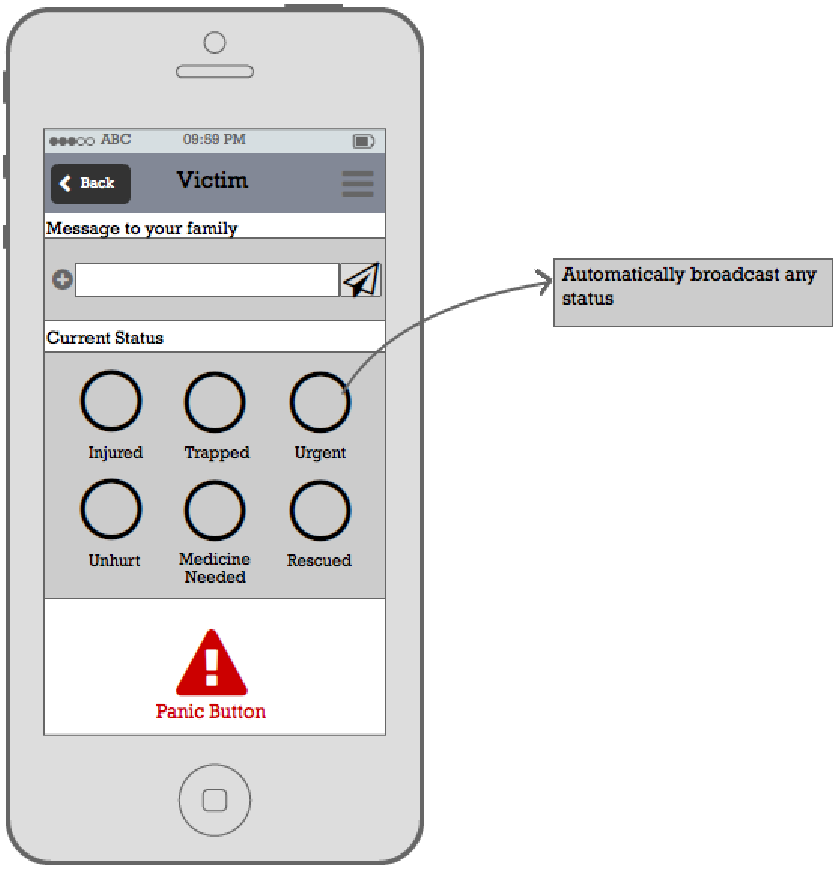
8. **8. Do you think that communication with text, picture and video is important in large-disaster situation?** *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

9. **9. Do you think PANIC BUTTON is useful in the large-disaster situation?** *

Victim Screen



Mark only only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

10. **10. Did you think that the application is user-friendly?** *

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	◯	◯	◯	◯	◯	Strongly Agree

11. **11. Please rate MKA overall design** *

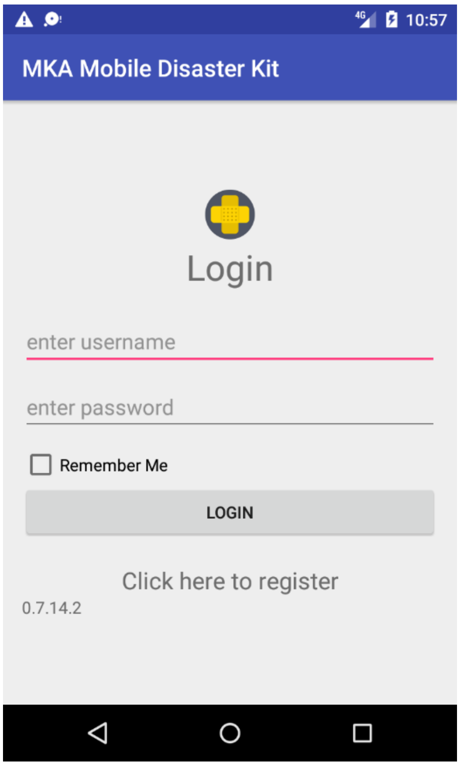
Mark only one oval.

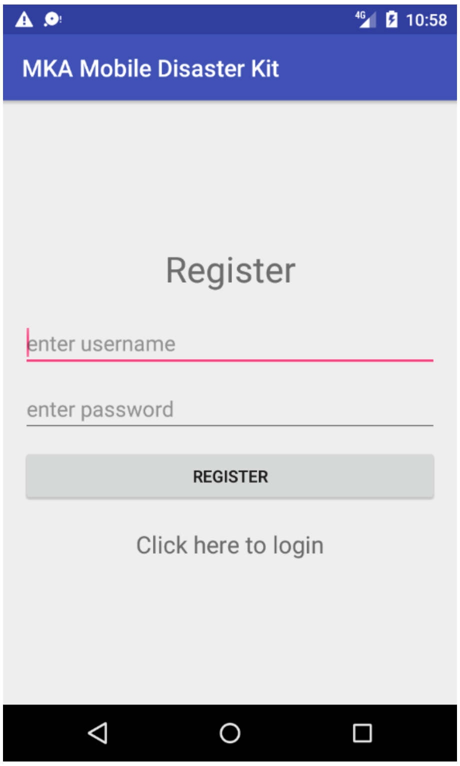
	1	2	3	4	5	
Bad	⬭	⬭	⬭	⬭	⬭	Excellent

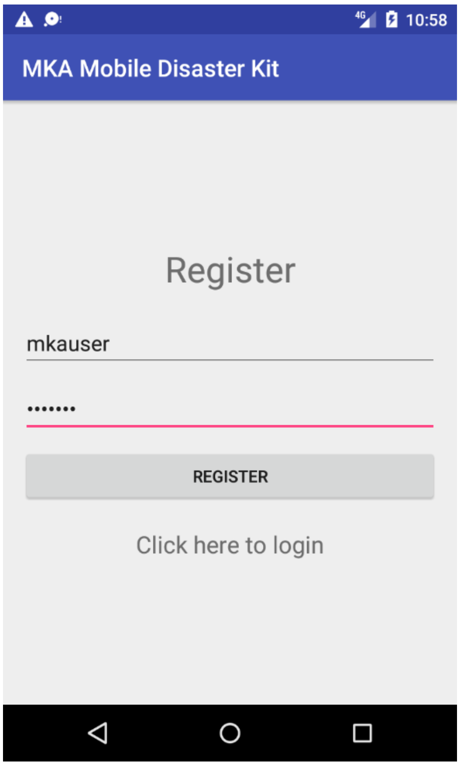
Powered by
Google Forms

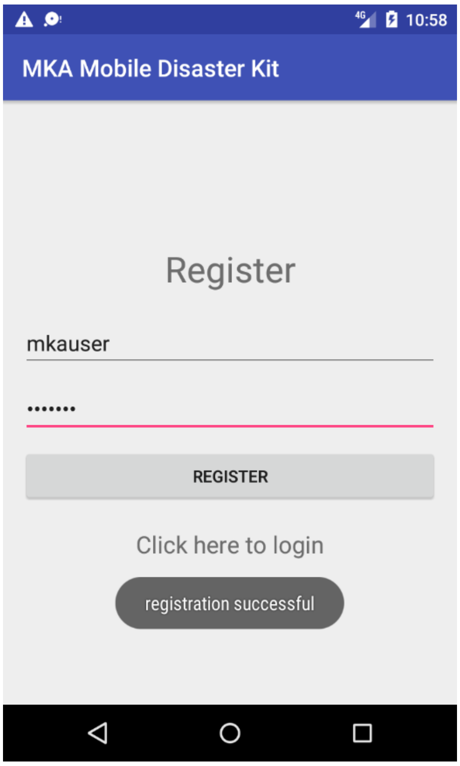
Appendix 2

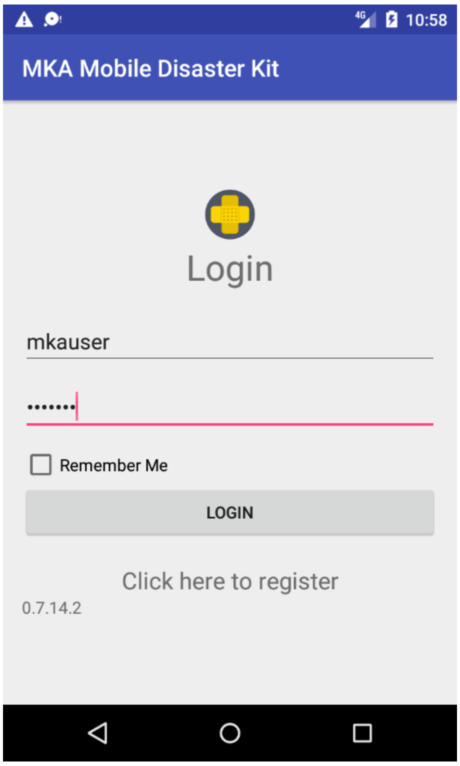
Overall MKA System Screens

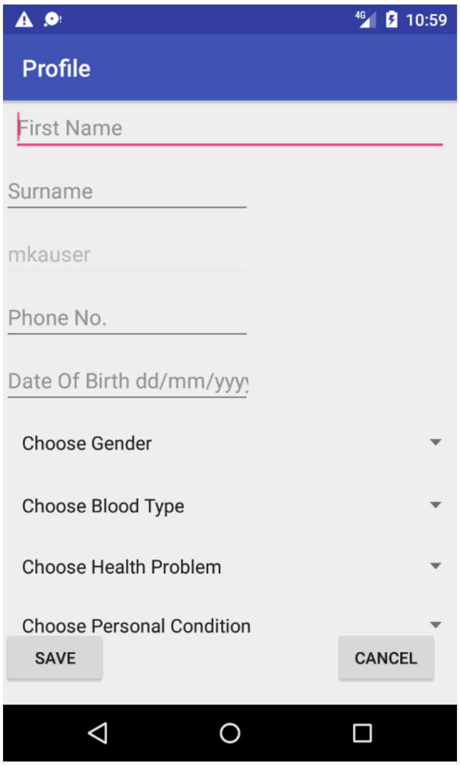


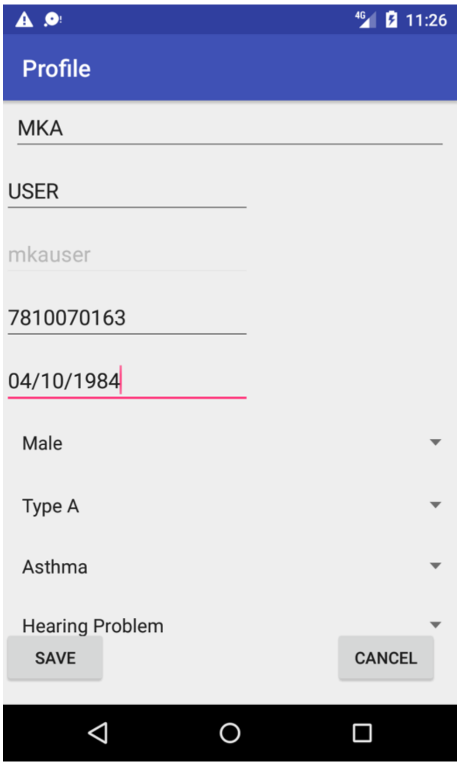


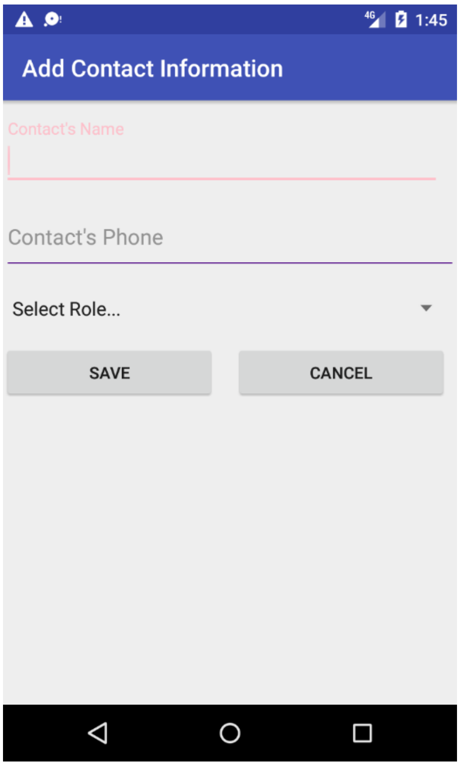


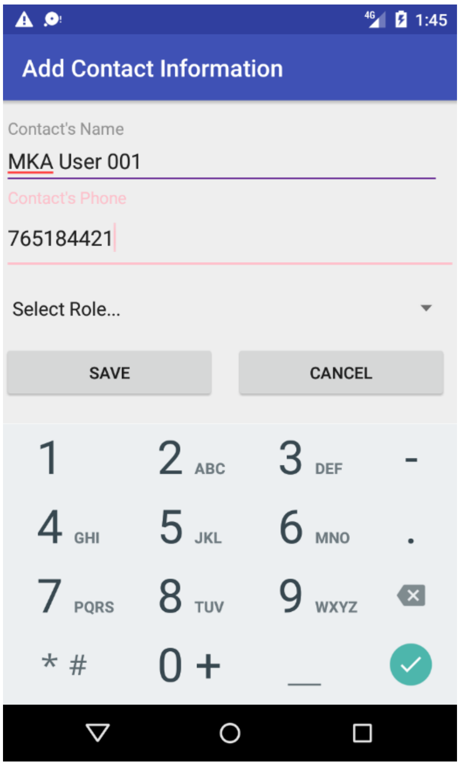


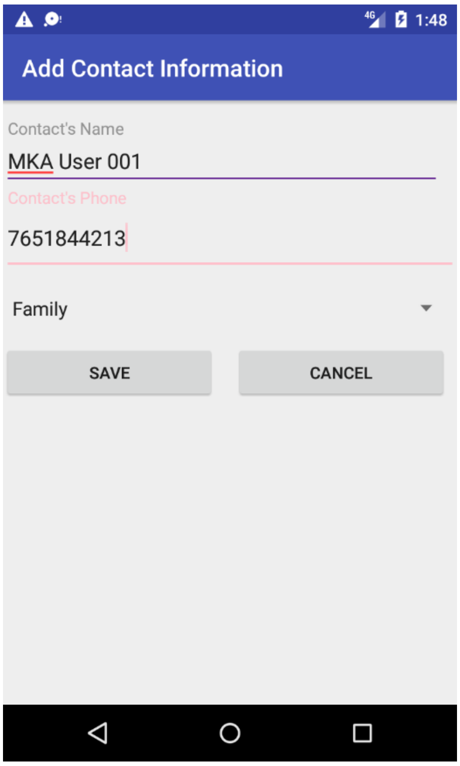

10:58
MKA Mobile Disaster Kit
Login
mkauser
Remember Me
LOGIN
Click here to register
0.7.14.2

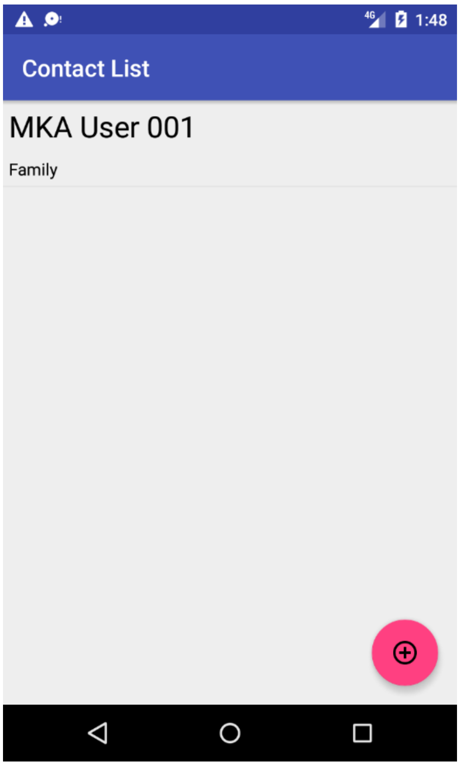

10:59
Profile
First Name
Surname
mkauser
Phone No.
Date Of Birth dd/mm/yyyy
Choose Gender
Choose Blood Type
Choose Health Problem
Choose Personal Condition
SAVE
CANCEL

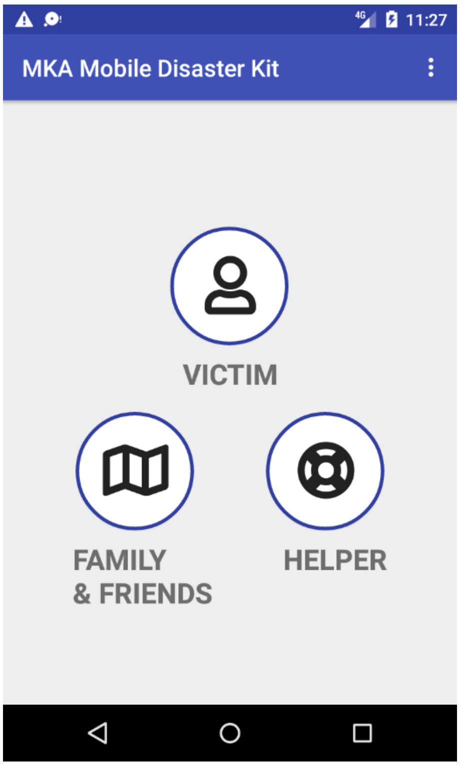

11:26
Profile
MKA
USER
mkauser
7810070163
04/10/1984
Male
Type A
Asthma
Hearing Problem
SAVE
CANCEL

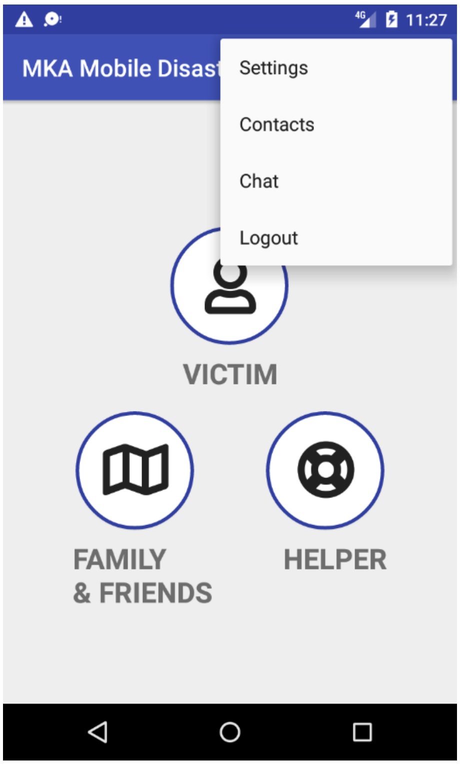

1:45
Add Contact Information
Contact's Name
Contact's Phone
Select Role...
SAVE
CANCEL

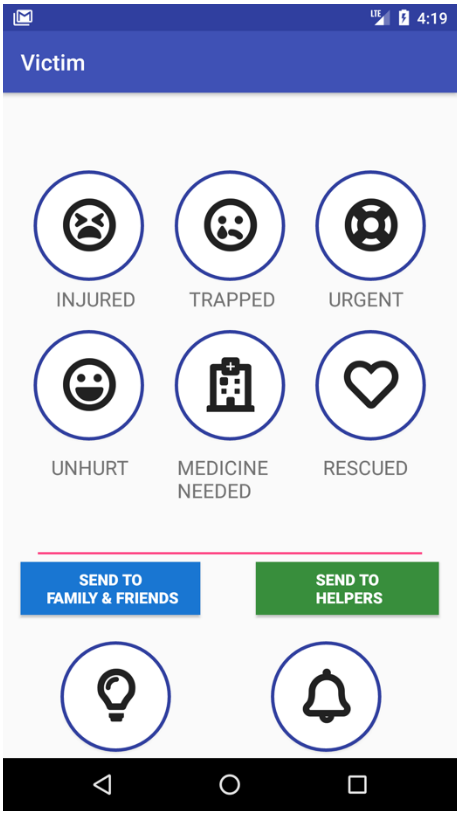

1:45
Add Contact Information
Contact's Name
MKA User 001
Contact's Phone
765184421
Select Role...
SAVE
CANCEL
1
2 ABC
3 DEF
-
4 GHI
5 JKL
6 MNO
.
7 PQRS
8 TUV
9 WXYZ
* #
0 +
_

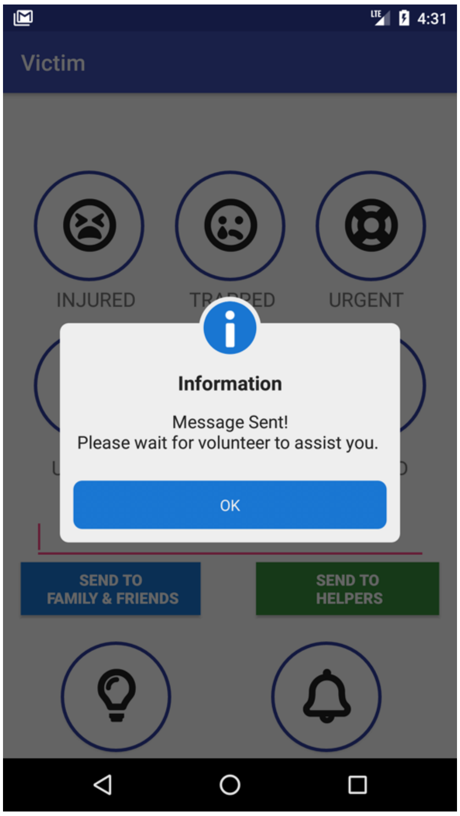

1:48
Add Contact Information
Contact's Name
MKA User 001
Contact's Phone
7651844213
Family
SAVE
CANCEL

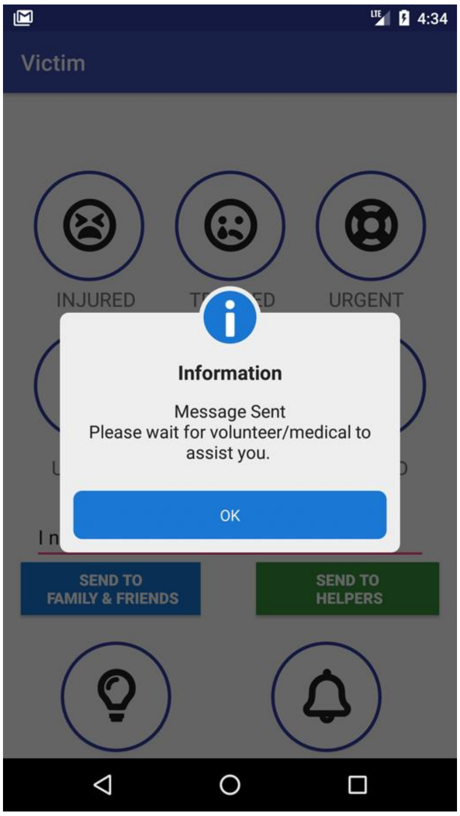

1:48
Contact List
MKA User 001
Family

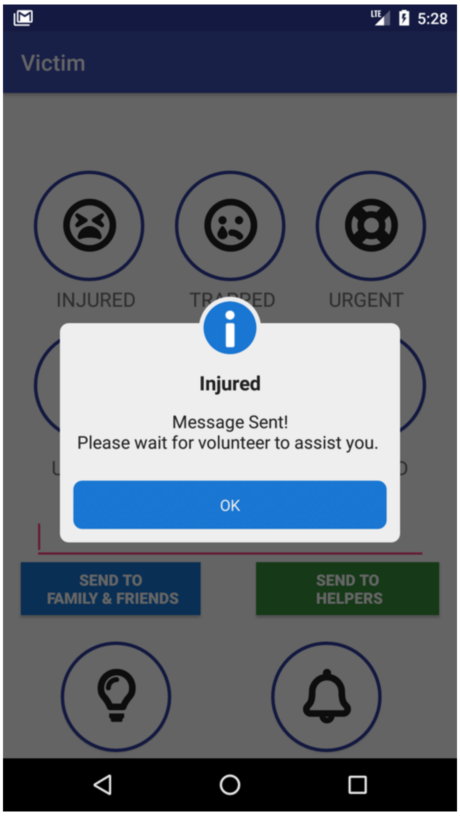

11:27
MKA Mobile Disaster Kit
VICTIM
FAMILY
& FRIENDS
HELPER

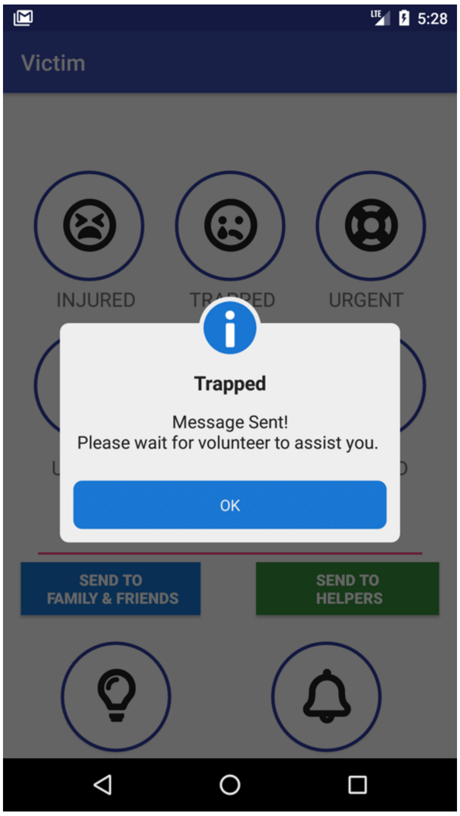

11:27
MKA Mobile Disast
Settings
Contacts
Chat
Logout
VICTIM
FAMILY & FRIENDS
HELPER

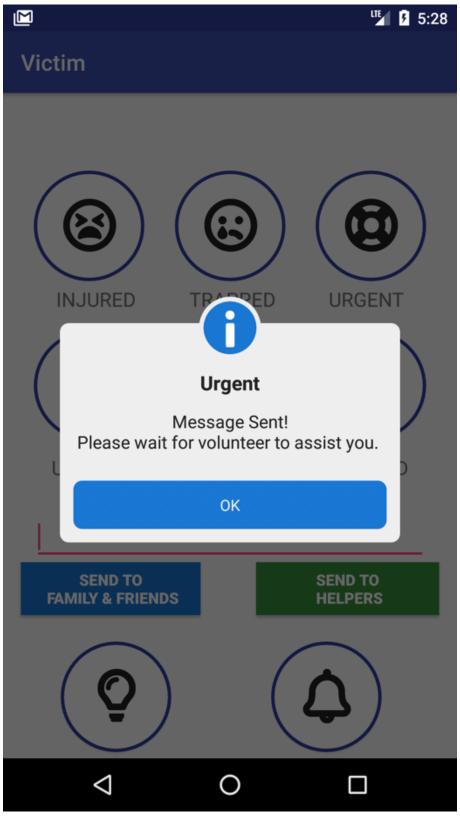

4:19
Victim
INJURED
TRAPPED
URGENT
UNHURT
MEDICINE NEEDED
RESCUED
SEND TO FAMILY & FRIENDS
SEND TO HELPERS

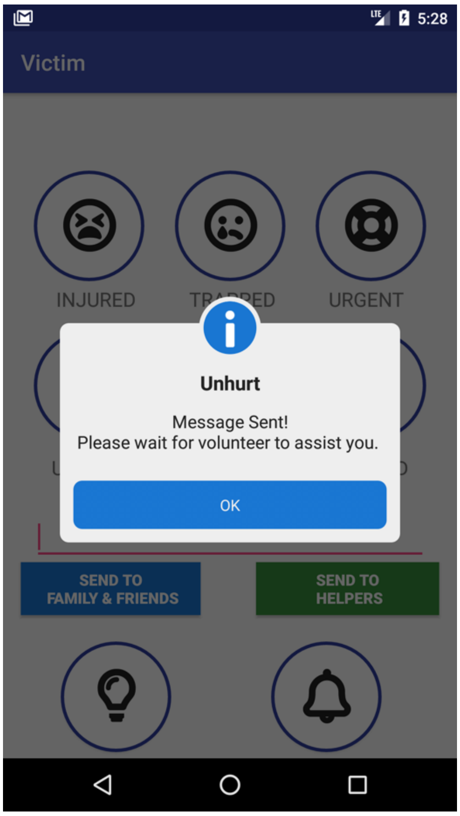

4:31
Victim
INJURED
URGENT
Information
Message Sent!
Please wait for volunteer to assist you.
OK
SEND TO FAMILY & FRIENDS
SEND TO HELPERS

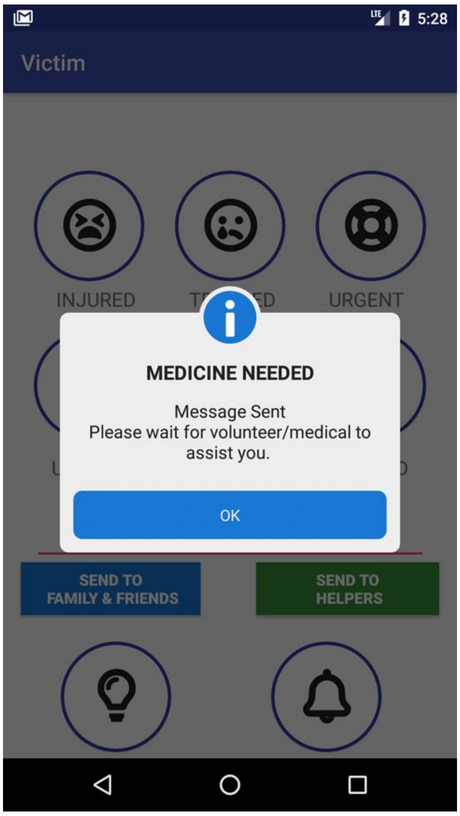

4:34
Victim
INJURED
URGENT
Information
Message Sent
Please wait for volunteer/medical to assist you.
OK
SEND TO FAMILY & FRIENDS
SEND TO HELPERS

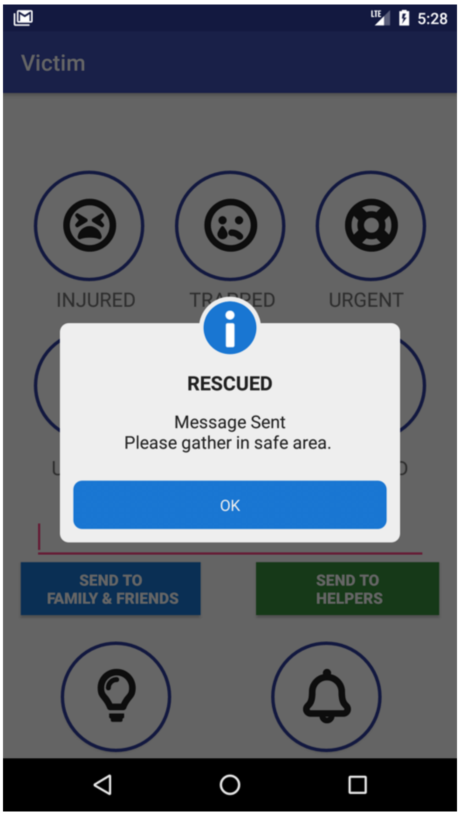

5:28
Victim
INJURED
URGENT
Injured
Message Sent!
Please wait for volunteer to assist you.
OK
SEND TO FAMILY & FRIENDS
SEND TO HELPERS

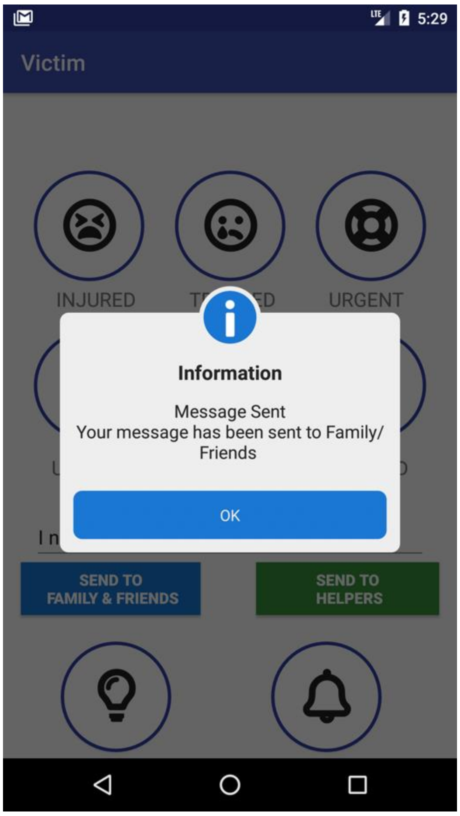

5:28
Victim
INJURED
URGENT
Trapped
Message Sent!
Please wait for volunteer to assist you.
OK
SEND TO FAMILY & FRIENDS
SEND TO HELPERS

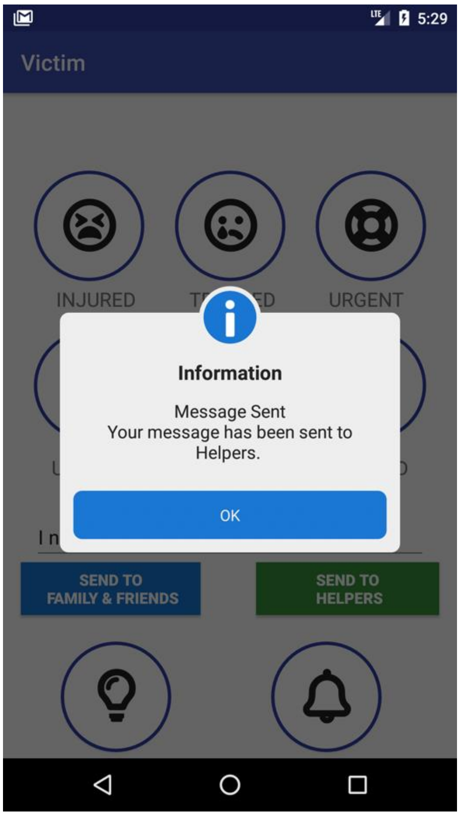

5:28
Victim
INJURED
URGENT
Urgent
Message Sent!
Please wait for volunteer to assist you.
OK
SEND TO FAMILY & FRIENDS
SEND TO HELPERS

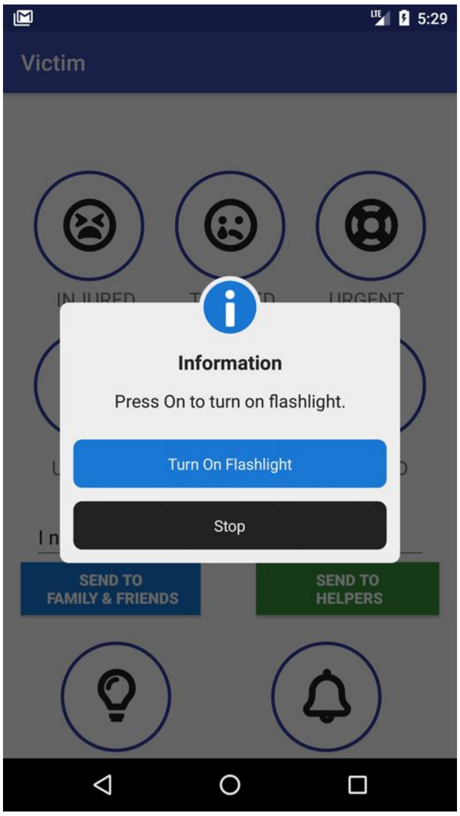

5:28
Victim
INJURED
URGENT
Unhurt
Message Sent!
Please wait for volunteer to assist you.
OK
SEND TO FAMILY & FRIENDS
SEND TO HELPERS

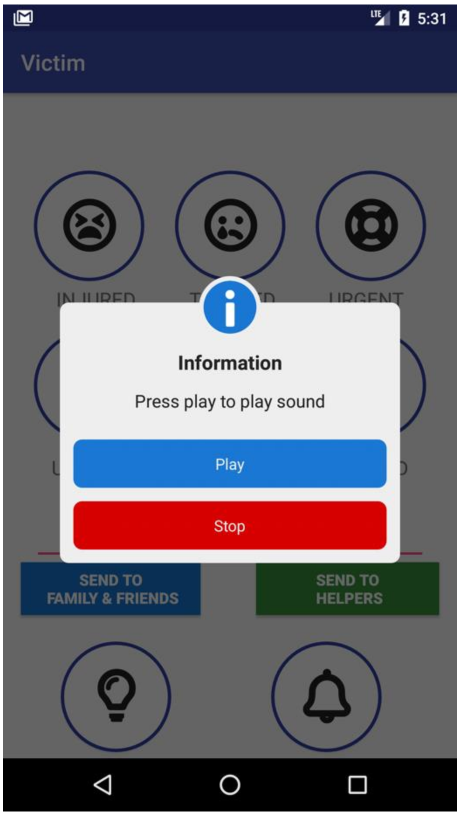

5:28
Victim
INJURED
URGENT
MEDICINE NEEDED
Message Sent
Please wait for volunteer/medical to assist you.
OK
SEND TO FAMILY & FRIENDS
SEND TO HELPERS

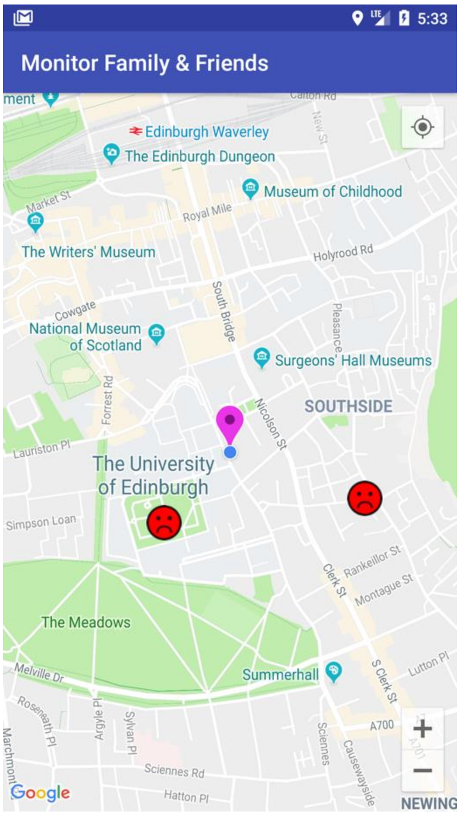

5:28
Victim
INJURED
URGENT
RESCUED
Message Sent
Please gather in safe area.
OK
SEND TO FAMILY & FRIENDS
SEND TO HELPERS

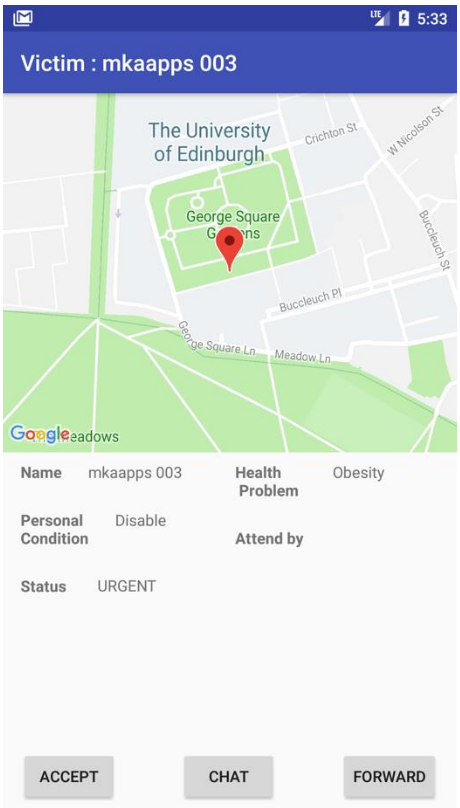

5:29
Victim
INJURED
URGENT
Information
Message Sent
Your message has been sent to Family/ Friends
OK
SEND TO FAMILY & FRIENDS
SEND TO HELPERS

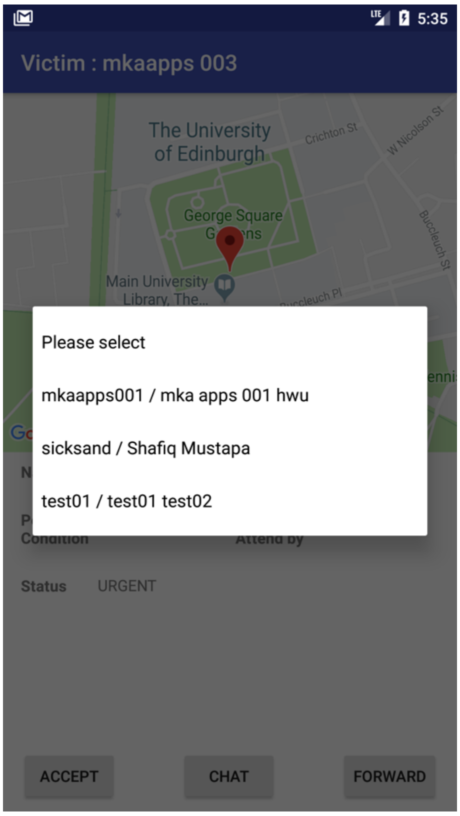

5:29
Victim
INJURED
URGENT
Information
Message Sent
Your message has been sent to Helpers.
OK
SEND TO FAMILY & FRIENDS
SEND TO HELPERS

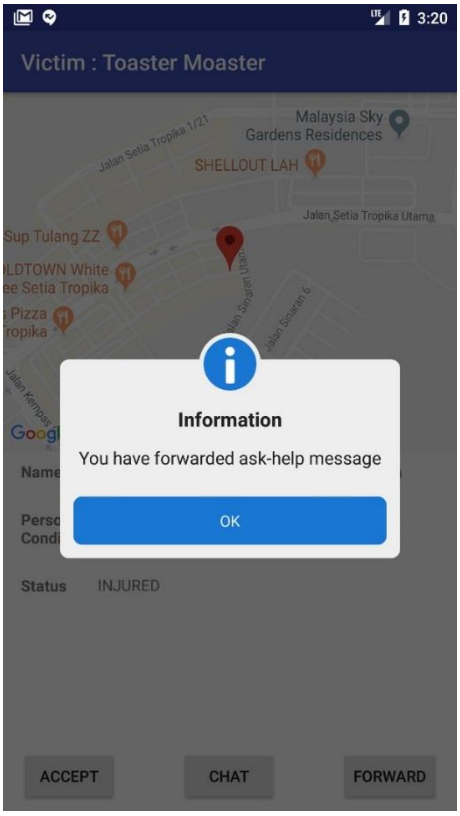

5:29
Victim
Information
Press On to turn on flashlight.
Turn On Flashlight
Stop
SEND TO
FAMILY & FRIENDS
SEND TO
HELPERS

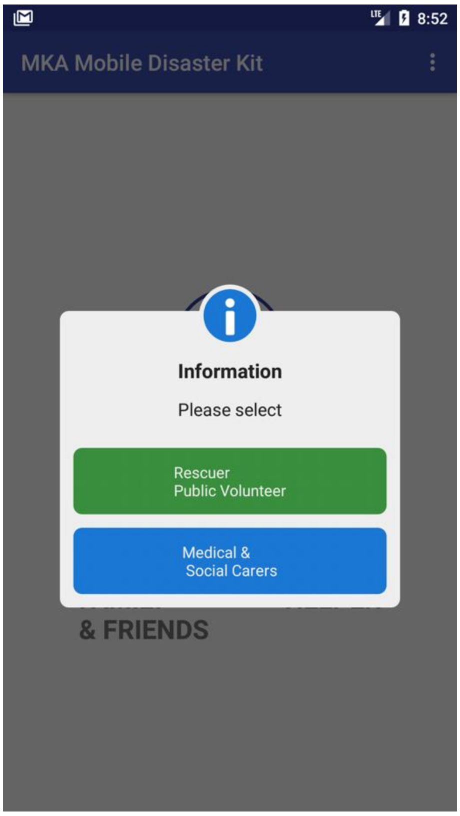

5:31
Victim
Information
Press play to play sound
Play
Stop
SEND TO
FAMILY & FRIENDS
SEND TO
HELPERS

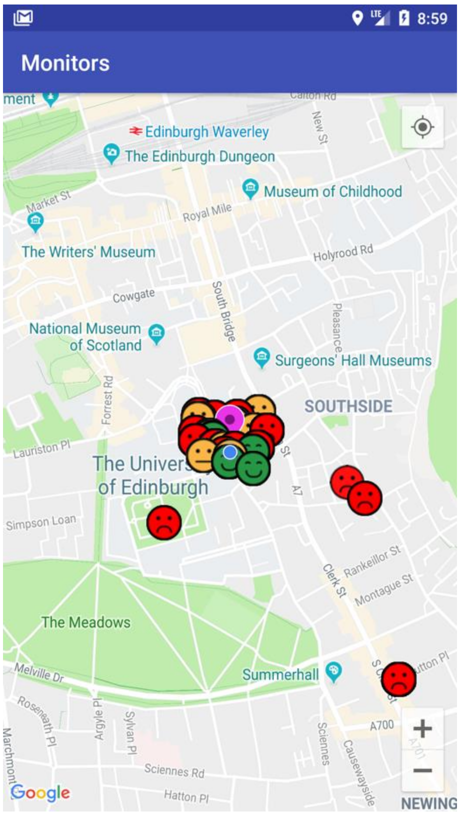

5:33
Monitor Family & Friends
Edinburgh Waverley
The Edinburgh Dungeon
Museum of Childhood
The Writers' Museum
National Museum
of Scotland
Surgeons' Hall Museums
SOUTHSIDE
The University
of Edinburgh
The Meadows
Summerhall
Google

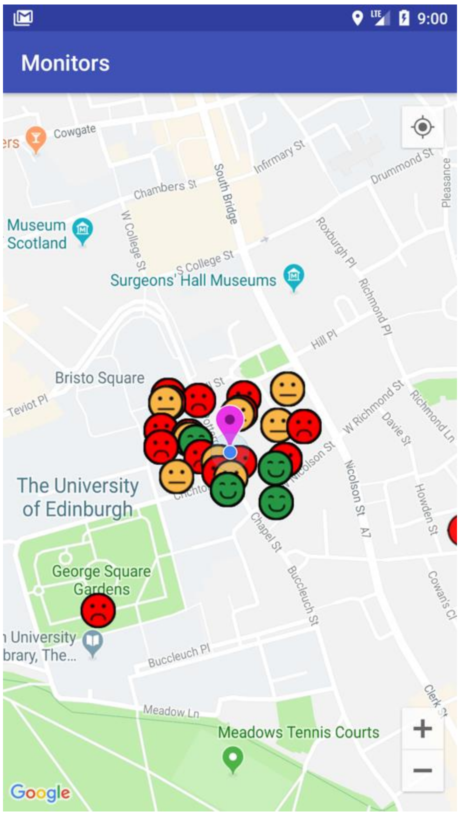

5:33
Victim : mkaapps 003
The University
of Edinburgh
George Square
Name
mkaapps 003
Health
Problem
Obesity
Personal
Condition
Disable
Attend by
Status
URGENT
ACCEPT
CHAT
FORWARD

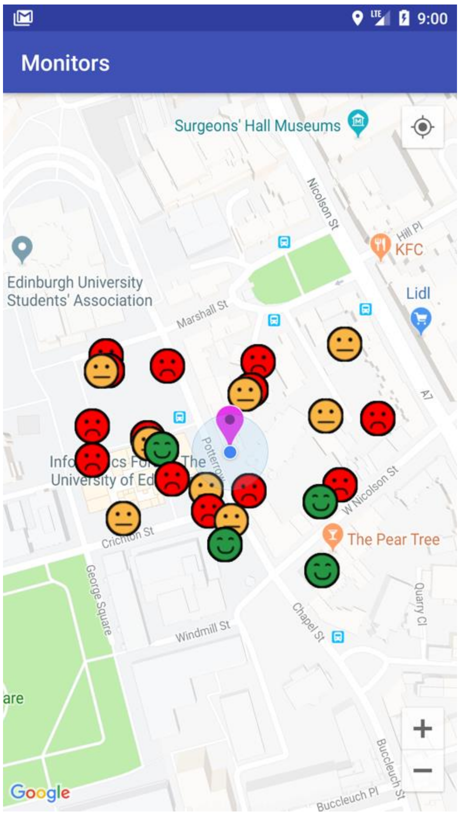

5:35
Victim : mkaapps 003
The University of Edinburgh
George Square Gardens
Main University Library, The...
Please select
mkaapps001 / mka apps 001 hwu
sicksand / Shafiq Mustapa
test01 / test01 test02
Status URGENT
ACCEPT
CHAT
FORWARD

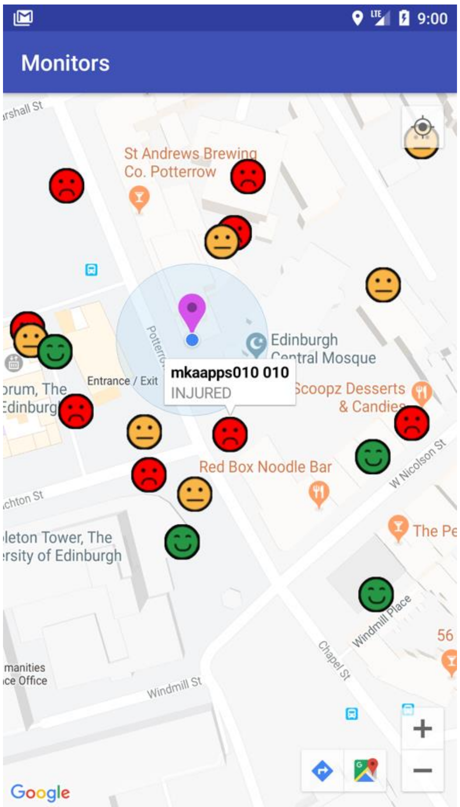

3:20
Victim : Toaster Moaster
Malaysia Sky Gardens Residences
SHELLOUT LAH
Information
You have forwarded ask-help message
OK
Status INJURED
ACCEPT
CHAT
FORWARD

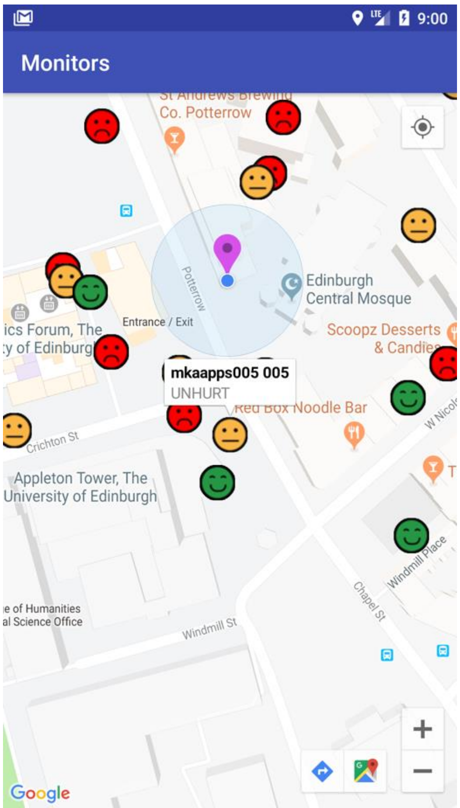

8:52
MKA Mobile Disaster Kit
Information
Please select
Rescuer
Public Volunteer
Medical &
Social Carers
& FRIENDS

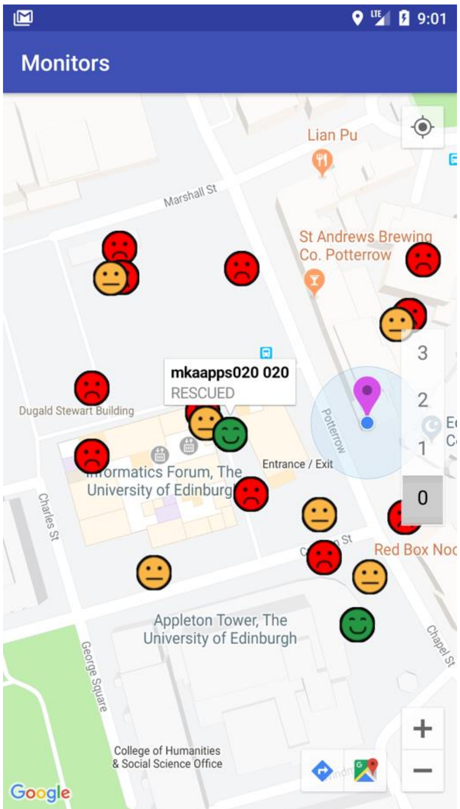

8:59
Monitors
Edinburgh Waverley
The Edinburgh Dungeon
Museum of Childhood
The Writers' Museum
National Museum of Scotland
Surgeons' Hall Museums
SOUTHSIDE
The University of Edinburgh
The Meadows
Summerhall
Google

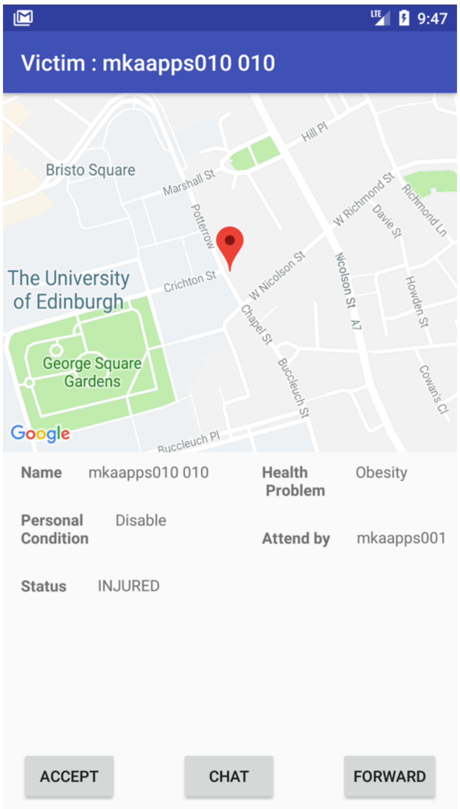

9:00
Monitors
Cowgate
Chambers St
South Bridge
Infirmary St
Drummond St
Pleasance
Museum
Scotland
W College St
S College St
Surgeons' Hall Museums
Roxburgh Pl
Richmond Pl
Hill Pl
Bristo Square
Teviot Pl
W Richmond St
Richmond Ln
Davie St
The University
of Edinburgh
Nicolson St
A7
Howden St
Chapel St
George Square
Gardens
Buccleuch St
Cowan's Cl
University
brary, The...
Buccleuch Pl
Meadow Ln
Meadows Tennis Courts
Google

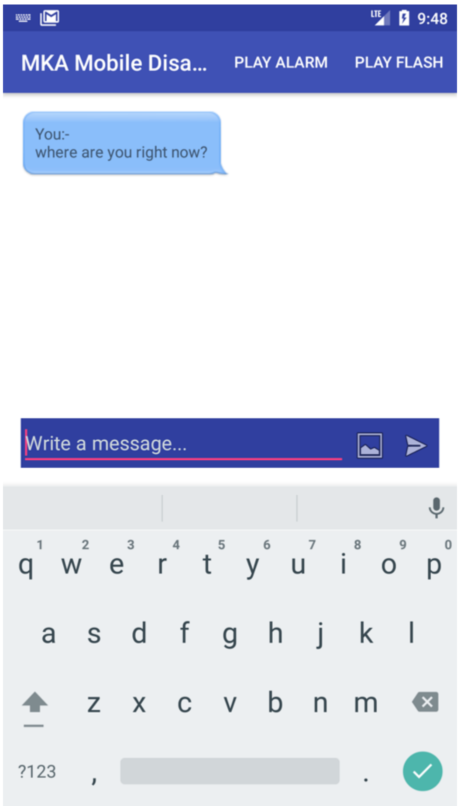

9:00
Monitors
Surgeons' Hall Museums
Nicolson St
Hill Pl
KFC
Lidl
Edinburgh University
Students' Association
Marshall St
A7
W Nicolson St
The Pear Tree
Crichton St
George Square
Chapel St
Quarry Cl
Windmill St
are
Buccleuch St
Buccleuch Pl
Google

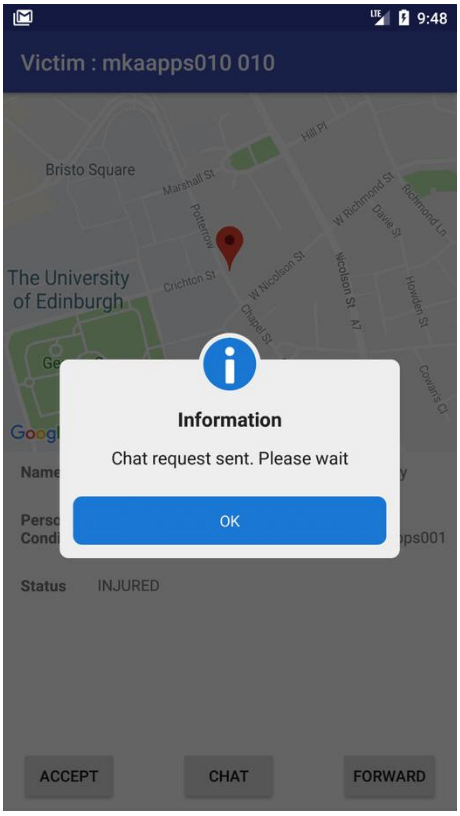

9:00
Monitors
rshall St
St Andrews Brewing
Co. Potterrow
Edinburgh
Central Mosque
Entrance / Exit
mkaapps010 010
INJURED
Scoopz Desserts
& Candies
Red Box Noodle Bar
W Nicolson St
The Pe
leton Tower, The
rsity of Edinburgh
Windmill Place
56
Chapel St
manities
ce Office
Windmill St
Google

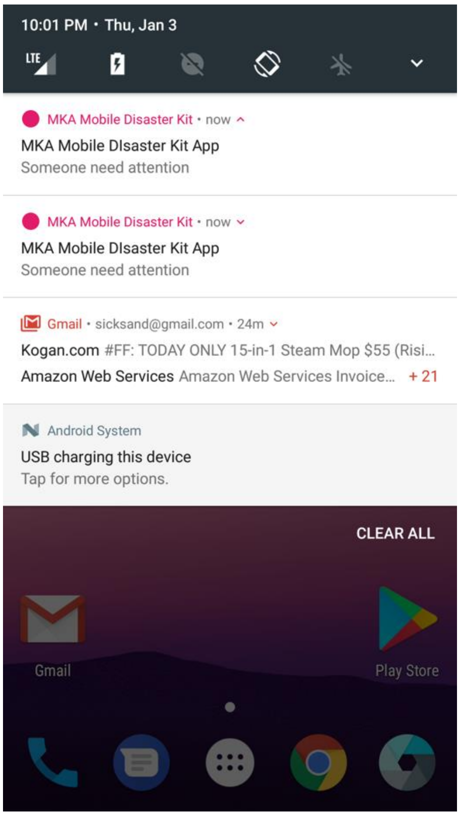

9:00
Monitors
Co. Potterrow
Potterrow
Edinburgh
Central Mosque
ics Forum, The
y of Edinburgh
Entrance / Exit
Scoopz Desserts
& Candie
mkaapps005 005
UNHURT
Red Box Noodle Bar
W Nicol
Crichton St
Appleton Tower, The
University of Edinburgh
Windmill Place
Chapel St
e of Humanities
al Science Office
Windmill St
Google

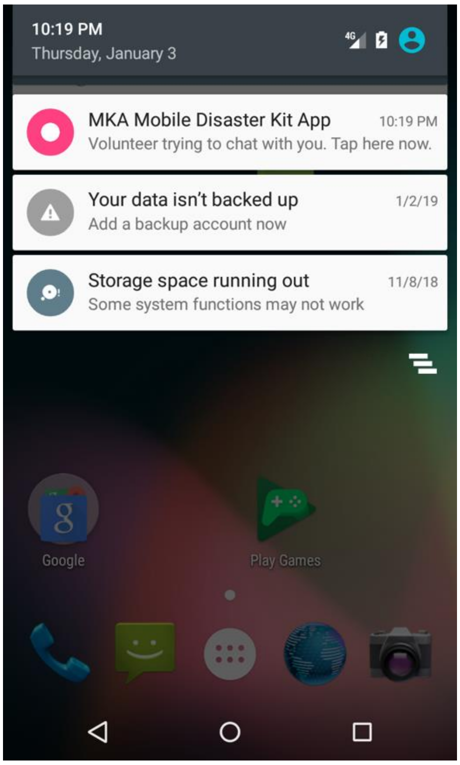

9:01
Monitors
Lian Pu
Marshall St
St Andrews Brewing Co. Potterrow
mkaapps020 020
RESCUED
Dugald Stewart Building
Informatics Forum, The University of Edinburgh
Entrance / Exit
Red Box Noo
Appleton Tower, The University of Edinburgh
Charles St
George Square
Chapel St
College of Humanities & Social Science Office
Google

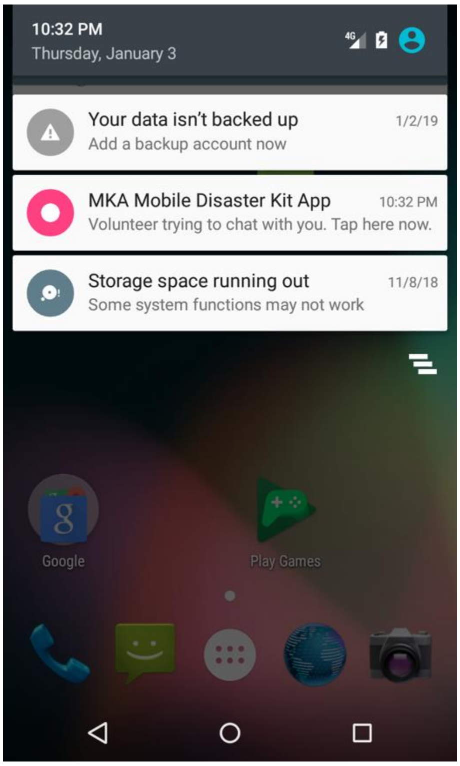

9:47
Victim : mkaapps010 010
Bristo Square
The University of Edinburgh
George Square Gardens
Google
Name mkaapps010 010
Health Problem Obesity
Personal Condition Disable
Attend by mkaapps001
Status INJURED
ACCEPT
CHAT
FORWARD

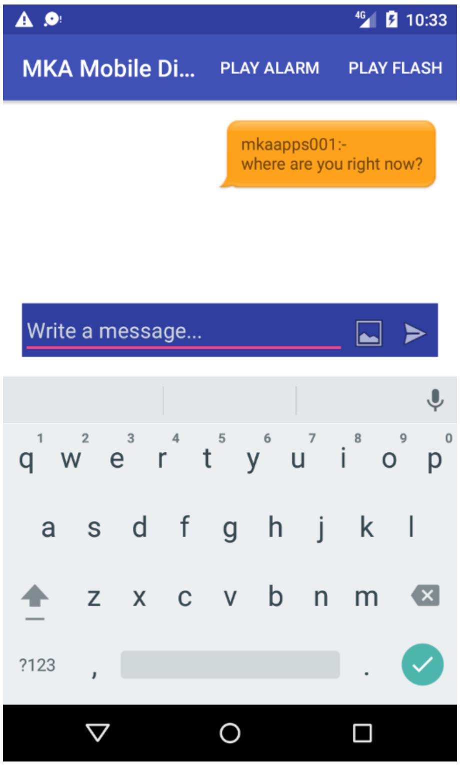

9:48
MKA Mobile Disa...
PLAY ALARM
PLAY FLASH
You:-
where are you right now?
Write a message...

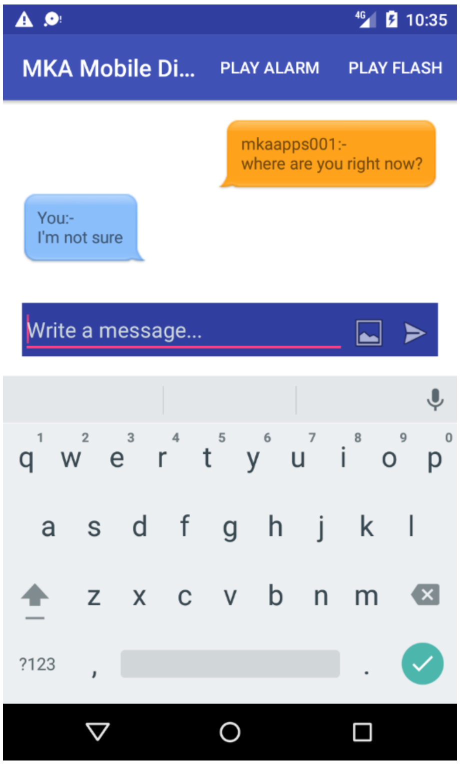

9:48
Victim : mkaapps010 010
Bristo Square
The University of Edinburgh
Information
Chat request sent. Please wait
OK
Status INJURED
ACCEPT
CHAT
FORWARD

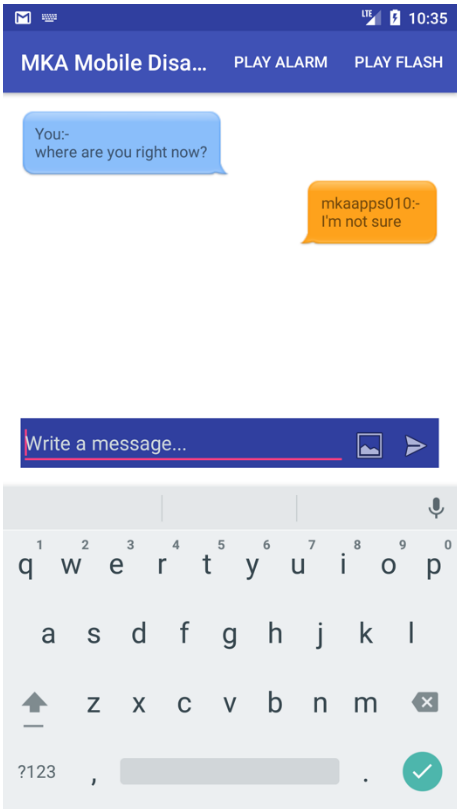

10:01 PM • Thu, Jan 3
MKA Mobile Disaster Kit • now
MKA Mobile DIsaster Kit App
Someone need attention
MKA Mobile Disaster Kit • now
MKA Mobile DIsaster Kit App
Someone need attention
Gmail • sicksand@gmail.com • 24m
Kogan.com #FF: TODAY ONLY 15-in-1 Steam Mop $55 (Risi...
Amazon Web Services Amazon Web Services Invoice... + 21
Android System
USB charging this device
Tap for more options.
CLEAR ALL
Gmail
Play Store

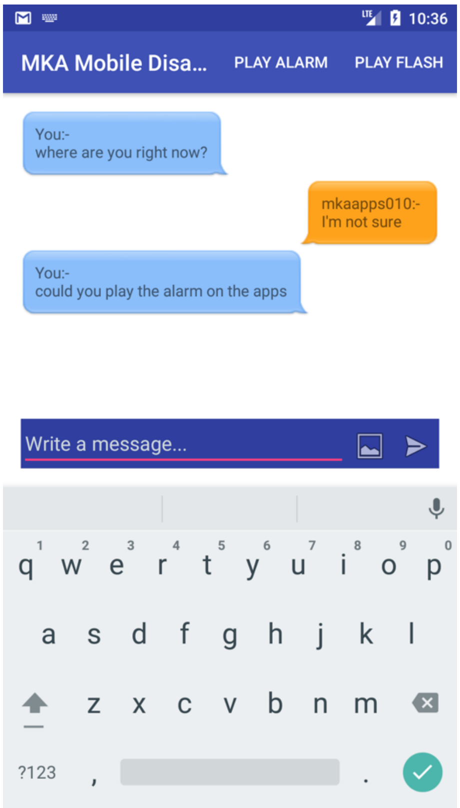

10:19 PM
Thursday, January 3
MKA Mobile Disaster Kit App 10:19 PM
Volunteer trying to chat with you. Tap here now.
Your data isn't backed up 1/2/19
Add a backup account now
Storage space running out 11/8/18
Some system functions may not work
Google
Play Games

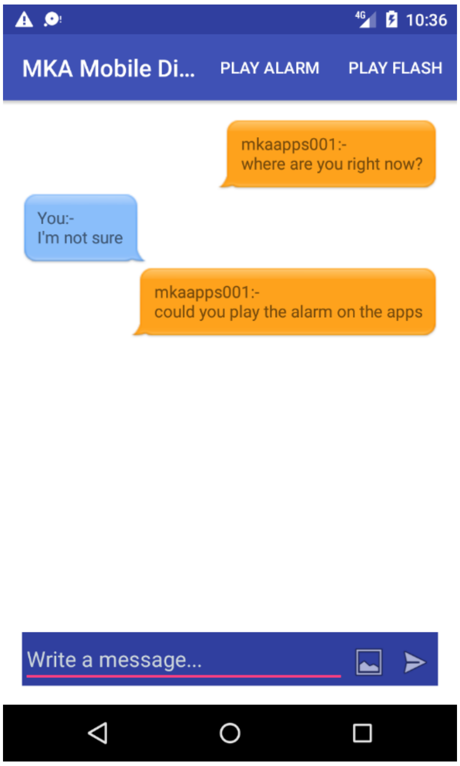

10:32 PM
Thursday, January 3
Your data isn't backed up 1/2/19
Add a backup account now
MKA Mobile Disaster Kit App 10:32 PM
Volunteer trying to chat with you. Tap here now.
Storage space running out 11/8/18
Some system functions may not work
Google
Play Games

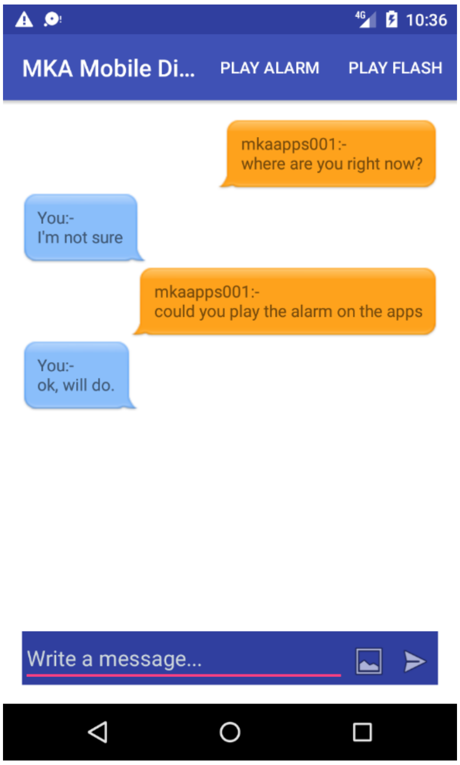

10:33
MKA Mobile Di...
PLAY ALARM
PLAY FLASH
mkaapps001:-
where are you right now?
Write a message...

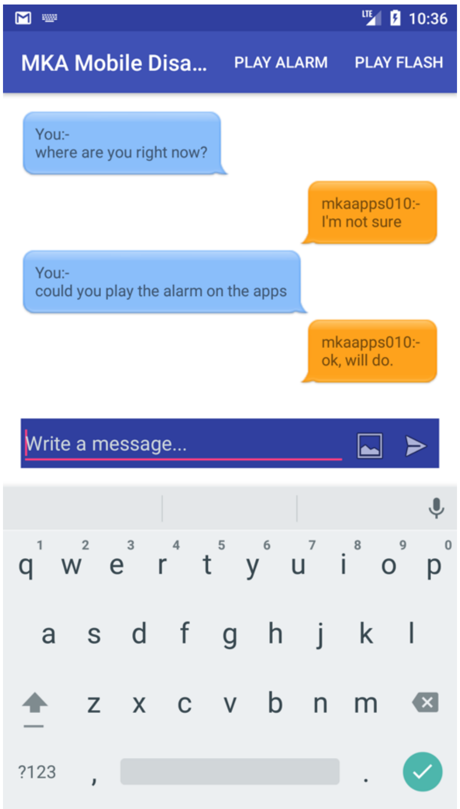

10:35
MKA Mobile Di...
PLAY ALARM
PLAY FLASH
mkaapps001:-
where are you right now?
You:-
I'm not sure
Write a message...

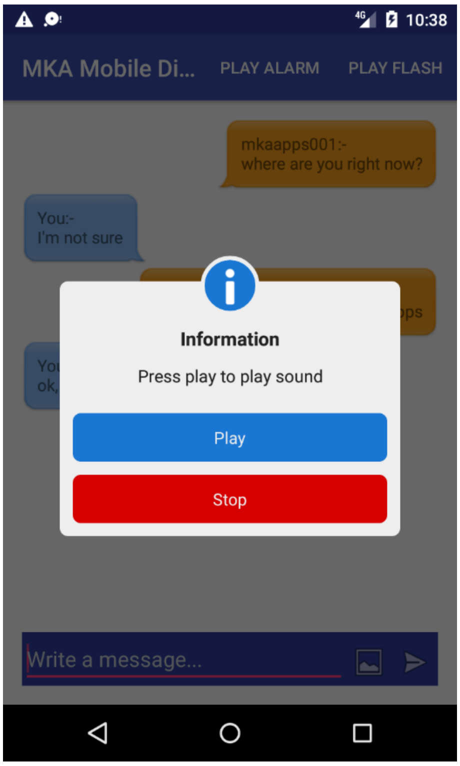

10:35
MKA Mobile Disa...
PLAY ALARM
PLAY FLASH
You:-
where are you right now?
mkaapps010:-
I'm not sure
Write a message...

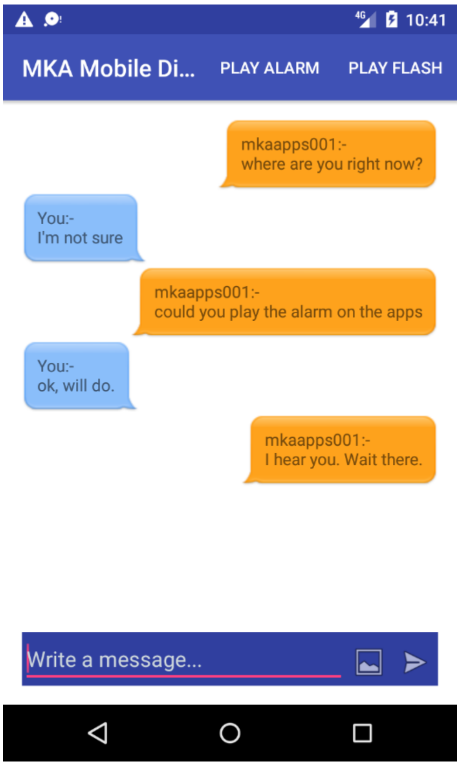

10:36
MKA Mobile Disa...
PLAY ALARM
PLAY FLASH
You:-
where are you right now?
mkaapps010:-
I'm not sure
You:-
could you play the alarm on the apps
Write a message...


10:36
MKA Mobile Di...
PLAY ALARM
PLAY FLASH
mkaapps001:-
where are you right now?
You:-
I'm not sure
mkaapps001:-
could you play the alarm on the apps
Write a message...


10:36
MKA Mobile Di...
PLAY ALARM
PLAY FLASH
mkaapps001:-
where are you right now?
You:-
I'm not sure
mkaapps001:-
could you play the alarm on the apps
You:-
ok, will do.
Write a message...


10:36
MKA Mobile Disa...
PLAY ALARM
PLAY FLASH
You:-
where are you right now?
mkaapps010:-
I'm not sure
You:-
could you play the alarm on the apps
mkaapps010:-
ok, will do.
Write a message...


10:38
MKA Mobile Di...
PLAY ALARM
PLAY FLASH
mkaapps001:-
where are you right now?
You:-
I'm not sure
Information
Press play to play sound
Play
Stop
Write a message...


10:41
MKA Mobile Di...
PLAY ALARM
PLAY FLASH
mkaapps001:-
where are you right now?
You:-
I'm not sure
mkaapps001:-
could you play the alarm on the apps
You:-
ok, will do.
mkaapps001:-
I hear you. Wait there.
Write a message...

Appendix 3

<u>Completeness of MKA System Requirements</u>

Please answer **Yes** or **No** for each question below:

Item	Requirements	Yes / No
1	The apps would utilise the smartphone basic features such as GNSS receiver, alarm, voice, messaging, camera, gestures.	
2	The apps would be able to communicate with each other using explicit messages that are short and to the point – to avoid unnecessary telecom congestion	
3	The apps would suggest a suitable (but simple) actions need to be taken during and after the disaster.	
4	The apps and data storage must be distributed and functioning in every device to make sure all the information can be accessed even when there is no internet connection	
5	Related data and emergency information must be given well-defined meaning in structural languages. Machines must be able to interpret it meaningfully.	
6	The app would keep sending pre-set messages automatically as appropriate, e.g. if the messages have not been replied or acknowledged, after they were first sent by victims. Random time should be used by each device in order to reduce network congestion until helpers accepted the request.	
7	The application would compile correctly and run on the smartphone (iPhone or Android)	
8	The app would be able to provide a robust communication mechanism, e.g. using a reliable communication protocol, so that senders know that his/her messages have been safely delivered to the targeted recipients, etc.	
9	The mobile app should use an appropriate level of power consumption to reduce battery usage so that the communication can remain as long as possible, as needed.	

Appendix 4

Correctness of MKA System Requirements

Please answer **Yes** or **No** for each question below:

Item	Requirements	Instructions	OK / Fail
1		Install MKA System on Android smartphone	
2		Launch MKA System from Android smartphone	
3		Sign-up and register your personal profile	
4		Login to the system	
5	The apps would utilise the smartphone basic features such as GNSS receiver, alarm, voice, messaging, camera, gestures.	Go to • Victim Menu -> Choose pre-set message • Sending custom message • Use flashlight and sound	
6	The apps would be able to communicate with each other using explicit messages that are short and to the point – to avoid unnecessary telecom congestion	Go to • Helper Menu • Choose one of the helper categories • Choose any random victims • Accept ask help message from victim • Chat with victim • Send and reply message	
7	The apps would suggest a suitable (but simple) actions need to be taken during and after the disaster.	• User should receive notification from MKA system • Helper can track victim using map function	

Item	Requirements	Instructions	OK / Fail
8	Related data and emergency information must be given well-defined meaning in structural languages. Machines must be able to interpret it meaningfully.	Go to • Helper screen • Choose one of the helper categories • Choose any random victims • Accept ask help message from victim • Helper can track victim using map function	
9	The app would keep sending pre-set messages automatically as appropriate, e.g. if the messages have not been replied or acknowledged, after they were first sent by victims. Random time should be used by each device in order to reduce network congestion until helpers accepted the request.	Go to • Victim Menu -> Choose pre-set message • Sending custom message	
10	The application would compile correctly and run on the smartphone (iPhone or Android)	• Install MKA System on Android smartphone • Launch MKA System from Android smartphone	
11	The app would be able to provide a robust communication mechanism, e.g. using a reliable communication protocol, so that senders know that his/her messages have been safely delivered to the targeted recipients, etc.	Pop up Message will appear when sending or forwarding a message to notify users	

Item	Requirements	Instructions	OK / Fail
12	The mobile app should use an appropriate level of power consumption to reduce battery usage so that the communication can remain as long as possible, as needed.	Random time used to resend an unaccepted message	

Appendix 5

Section 1 – Evaluation of the Mobile Kit Disaster Assistant (MKA) Assistant Framework

1. **Do you agree mobile applications can and should play a vital role in helping emergency response in large-scale of disasters?**

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

2. **Do you agree the following functionalities on mobile phones play a vital role to enable effective and personalised communication, thus help emergency response efforts to reach victims quickly to decrease fatalities in large-scale of disasters?**

   a. Alert and warning functions

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

   b. Tracking exact locations of victims using text, voice and videos

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

   c. Multi-gestures, inc. tap, touch screen, vibration, sound, movement (moving/shaking the phone) and (text) auto-reporting

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

   d. Other mobile phone functions that may be used to decrease the fatalities:

   ____

3. **Evaluate the usefulness of the Group of People components in mobile communication**

a. Is it important to communicate with the following groups of people during the Emergency Response?

Groups	Not important	Slightly Important	Moderately Important	Important	Very Important
Victims	☐	☐	☐	☐	☐
Family & Friends	☐	☐	☐	☐	☐
Rescue workers and Public Volunteers	☐	☐	☐	☐	☐
Medical and Social Carers	☐	☐	☐	☐	☐

b. Any other groups of people that should be kept informed; or if you have any comments on this section:

____

4. **Do you agree that personalised mobile application system with personal data and current situation stored in each device will help people in large-scale of disaster?**

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

5. **Do you agree that automated communication is very important during the emergency response? e.g. automatic reply victim's life's status to helper?**

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

6. **The MKA framework is an adaption of an existing Emergency Response standard. Do you agree the MKA communication cycle is appropriate and useful?**

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

Any missing components? Any other comments?

____

7. **Do you agree the overall MKA response framework is useful?**

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

Any comments?

____

Section 2 – Evaluation of The Communication and Tracking Ontology (CTO)

1. Do you agree ontologies can be suitably used to represent and store knowledge of disaster and emergency response for mobile phone uses?

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

Any comments:

____

2. Do you agree it is important to keep track of the following knowledge items in emergency response efforts?

Classes	Not important	Slightly Important	Moderately Important	Important	Very Important
Agent	☐	☐	☐	☐	☐
Communication Mechanism	☐	☐	☐	☐	☐
Data Type	☐	☐	☐	☐	☐
Resources	☐	☐	☐	☐	☐
Early Warning System	☐	☐	☐	☐	☐
ER-Agent Communication Language	☐	☐	☐	☐	☐
Event	☐	☐	☐	☐	☐
Facility	☐	☐	☐	☐	☐
Location	☐	☐	☐	☐	☐
Phase of Event	☐	☐	☐	☐	☐
Role	☐	☐	☐	☐	☐
Terrain	☐	☐	☐	☐	☐
Time	☐	☐	☐	☐	☐
TimeZone	☐	☐	☐	☐	☐
Wireless Communication	☐	☐	☐	☐	☐

Any suggestions, e.g. missing knowledge items:

____

3. **Do you agree that CTO has grouped relevant knowledge appropriately, esp. in the sub-class structure (branches)?**

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

4. **Do you think these classes may be re-organised? If so, how? Any new branches that may be considered?**

Section 3 – Evaluation of ER Agent Communication Language (ER-ACL)

1. **To what extent do you agree the following performative is important in ER-ACL?**

Performative	Not important	Slightly Important	Moderately Important	Important	Very Important
Ask-help	☐	☐	☐	☐	☐
Ask-help-forward	☐	☐	☐	☐	☐
Offer-help	☐	☐	☐	☐	☐
Accept	☐	☐	☐	☐	☐
Acknowledge	☐	☐	☐	☐	☐
Send	☐	☐	☐	☐	☐
Reply-to	☐	☐	☐	☐	☐
Reply-with	☐	☐	☐	☐	☐
Status-report	☐	☐	☐	☐	☐
Channel	☐	☐	☐	☐	☐

Any comments or performatives that you would like to add?

___

2. **To what extent do you agree to exchange the following information between sender and receiver is important?**

Information	Not important	Slightly Important	Moderately Important	Important	Very Important
Time Stamp	☐	☐	☐	☐	☐
Sender Name	☐	☐	☐	☐	☐
Receiver Name	☐	☐	☐	☐	☐
Event of Category	☐	☐	☐	☐	☐
Event of Type	☐	☐	☐	☐	☐
Severity of event	☐	☐	☐	☐	☐
Impact of location (e.g. what happens to my building – e.g. collapsed/damaged; what happened to the street – e.g. high of the flood) – can be transmitted via a message, should be	☐	☐	☐	☐	☐

Information	Not important	Slightly Important	Moderately Important	Important	Very Important
defined in the ontology – and can be send as a text message.					
User Role	☐	☐	☐	☐	☐
Content of Text Message	☐	☐	☐	☐	☐
Picture Message	☐	☐	☐	☐	☐
Video Message	☐	☐	☐	☐	☐
Voice Message	☐	☐	☐	☐	☐
Last Location	☐	☐	☐	☐	☐
Current Location	☐	☐	☐	☐	☐
Battery Status	☐	☐	☐	☐	☐
Life Status	☐	☐	☐	☐	☐

Any comment or maybe you want to add a new information item?

____

Section 4 – Evaluation of ER Agent Communication Protocol (ER-ACP)

1. **Do you agree the following scenarios happen frequently and therefore are important to be managed structurally and systematically during disaster response/rescue?**

Scenario	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
Victim asking help from public volunteers and official rescuer workers	☐	☐	☐	☐	☐
Victims asking help from their family and friends	☐	☐	☐	☐	☐
Victims asking help from rescue workers and medical support via their family and friends	☐	☐	☐	☐	☐
Victims asking help from medical professionals and social care-taker (esp. when official rescue workers have not reached them yet)	☐	☐	☐	☐	☐
Volunteers and rescuers offer help to victims	☐	☐	☐	☐	☐
Volunteers coordinate among themselves via mobile phones to offer emergency response	☒	☐	☐	☐	☐

Any comment or scenarios that you may want to add?

____

2. **To avoid network congestion and thereby communication breakdown, it is important to reduce un-necessary traffic during large-scale of disasters. Do you believe every sent message must be confirmed of receipt via a reply (acknowledge) message?**

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

Any comments:

____

3. **Do you think the function of forwarding ask-help message to other potential helpers, in the case of refusal to offer help, is important in the ask-help scenarios?**

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

4. **To what extent do you think the following agent is very important and therefore should be included in our framework in the communication cycle during large-scale of disaster?**

Groups	Not important	Slightly Important	Moderately Important	Important	Very Important
Victim	☐	☐	☐	☐	☐
Family & Friend	☐	☐	☐	☐	☐
Rescuer and Public Volunteer	☐	☐	☐	☐	☐
Medical and Social Carers	☐	☐	☐	☐	☐

Any other suggestions:

____

5. To what extent do you agree the way ER-ACP is consolidated, appropriate, useful and practical?

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

Any comments:

____

Section 5 – Mobile System Requirement and Design

1. Do you agree the following requirement is important to mobile application for emergency response?

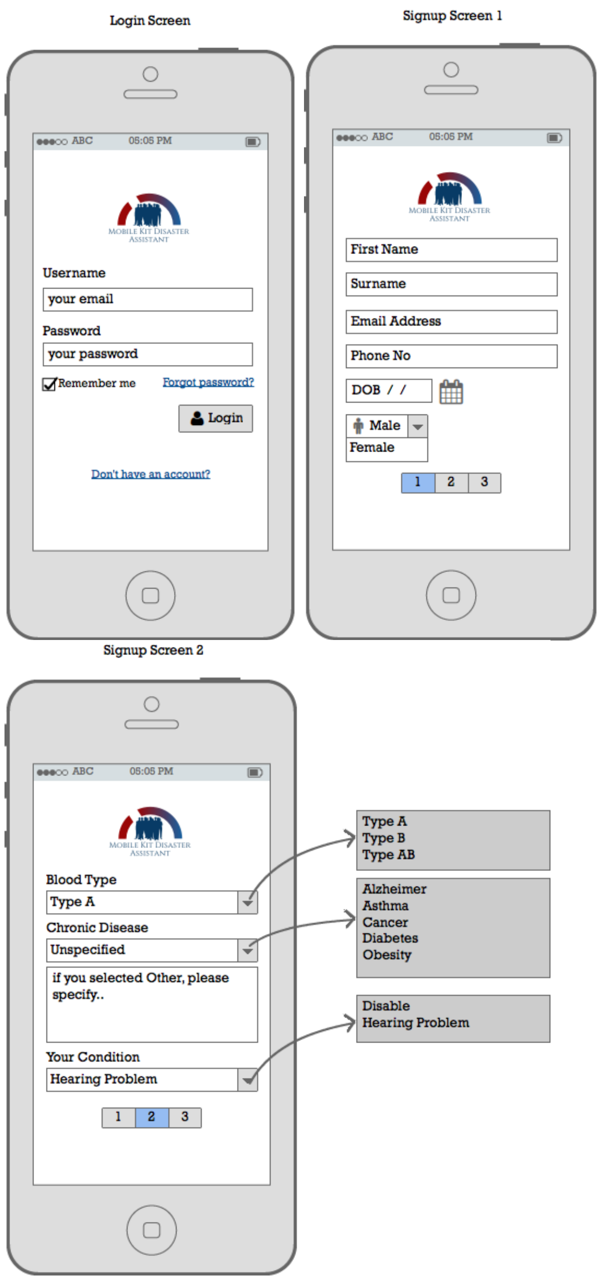
Item	Requirement	Yes	No
1	ER response communication medium should be mobile, light weight so can be easily carried to be used to the disaster-struck areas. Mobile phones and tablets are ideal mediums.		
2	The mobile apps should utilise the smart phone basic features such as GNSS receiver, alarm, voice, messaging, camera, gestures, motion and shaking.		
3	The mobile apps should be able to communicate with each other using explicit messages that are short and to the point – to avoid unnecessary telecom network congestion		
4	The mobile apps should suggest a suitable (but simple) actions need to be taken during and after the disaster.		
5	The information shared and stored in mobile apps must be appropriate, so to ensure necessary information is available even when there is no internet connection		
6	The application should compile correctly and run on smart phone (iPhone or Android)		
7	The communication should be short but clear and effective, so can conserve network usage.		
8	The communication flow between parties should be well-defined and structured, e.g. prescribed in a protocol, so that rigorous approaches are followed to avoid miscommunications.		
9	The message structure should be well-defined, so that messages may be understood and processed by the machines and their users.		
10	The commonly used message content and message types should be well-defined, so that messages may be short, but their meaning understood and processed by the machines and their users.		
11	The mobile app should be able to ensure a robust communication mechanism, e.g. in a reliable communication protocol, so that senders know that his/her messages have been safely delivered to the targeted recipients.		
12	The mobile apps should use an appropriate level of power consumption to reduce battery usage, so that the communication can remain as long as possible.		

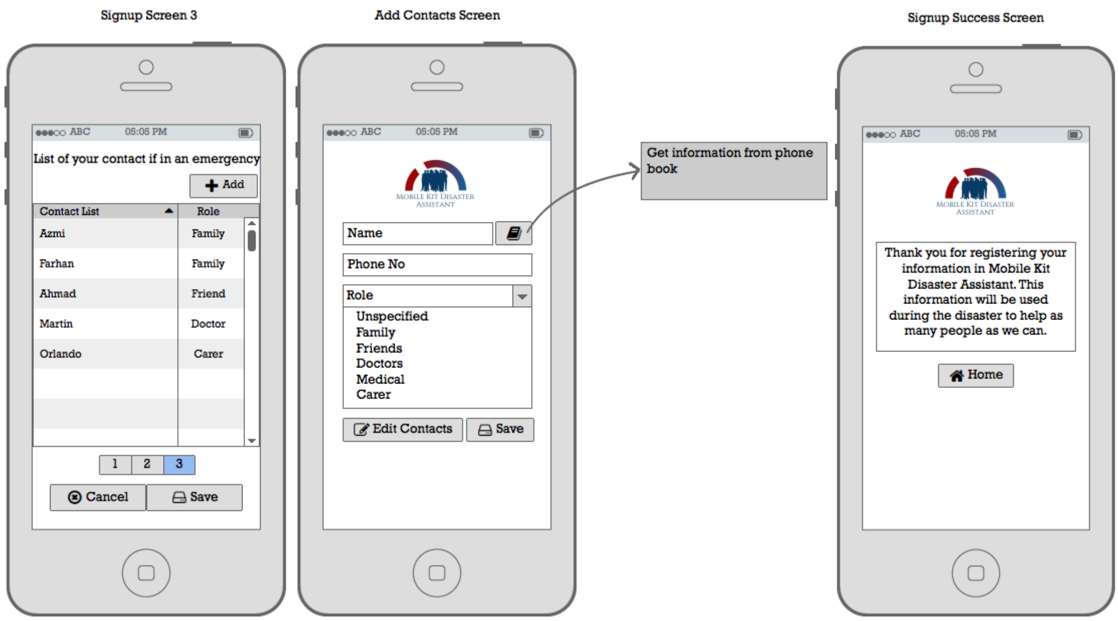
Item	Requirement	Yes	No
13	The mobile apps should use a simple colour system, where appropriate, e.g. use red, yellow and green to show victim's well-being and life status.		

Any comment or maybe you want to add new requirements to the mobile application system?

Section 6 – MKA Mobile Application Mock Up Design

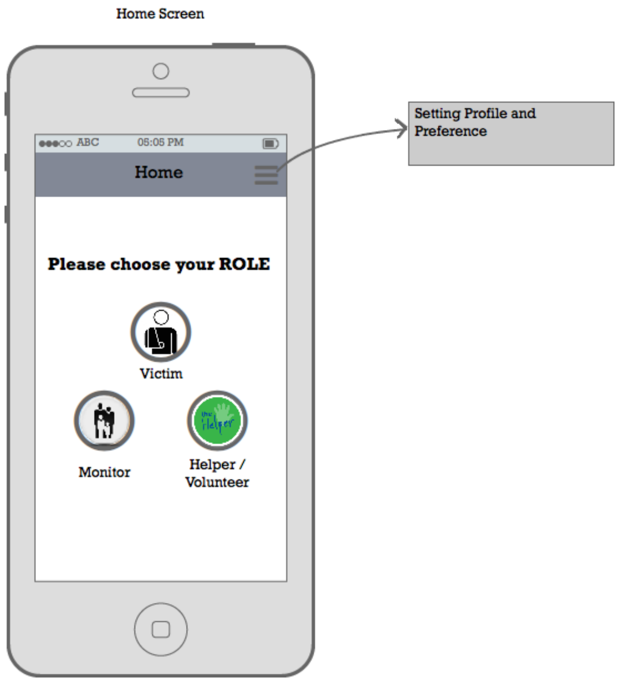
1. Do you agree the following design for users to record their personal information is very useful?





Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

2. **Do you agree the following design make you feel easy and understand your role?**



Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

3. **Do you agree the following design with maps function is useful for this apps?**

Monitoring Screen

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

4. **Do you agree the following design with three colours indication is easier to understand? (green, amber, red)**

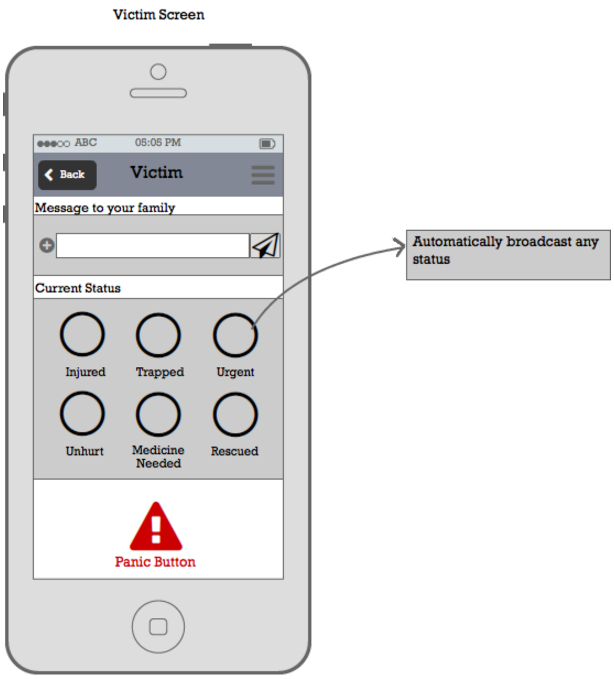
Volunteer / Helper Screen

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

5. **Do you agree the following design with text, picture and video messaging is important in the disaster situation?**

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

6. **Do you agree the following design with PANIC BUTTON is useful in the disaster situation?**



Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

7. **Do you agree the overall design is user-friendly?**

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

8. **Do you agree the overall design is suitable to support real-world emergency response scenarios?**

Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
☐	☐	☐	☐	☐

Appendix 6

System Usability Scale (SUS) for MKA Mobile App

1. **1. I think that I would like to use this system frequently.**
Mark only one oval.

	1	2	3	4	5	
Strongly disagree	⬭	⬭	⬭	⬭	⬭	Strongly agree

2. **2. I found the system unnecessarily complex.**
Mark only one oval.

	1	2	3	4	5	
Strongly disagree	⬭	⬭	⬭	⬭	⬭	Strongly Agree

3. **3. I thought the system was easy to use.**
Mark only one oval.

	1	2	3	4	5	
Strongly disagree	⬭	⬭	⬭	⬭	⬭	Strongly Agree

4. **4. I think that I would need the support of a technical person to be able to use this system.**
Mark only one oval.

	1	2	3	4	5	
Strongly disagree	⬭	⬭	⬭	⬭	⬭	Strongly Agree

5. **5. I found the various functions in this system were well integrated.**
Mark only one oval.

	1	2	3	4	5	
Strongly disagree	⬭	⬭	⬭	⬭	⬭	Strongly Agree

6. **6. I thought there was too much inconsistency in this system.**
Mark only one oval.

	1	2	3	4	5	
Strongly disagree	⬭	⬭	⬭	⬭	⬭	Strongly Agree

7. **7. I would imagine that most people would learn to use this system very quickly.**
Mark only one oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly Agree

8. **8. I found the system very cumbersome to use.**
Mark only one oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly Agree

9. **9. I felt very confident using the system.**
Mark only one oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly Agree

10. **10. I needed to learn a lot of things before I could get going with this system.**
Mark only one oval.

	1	2	3	4	5	
Strongly disagree	◯	◯	◯	◯	◯	Strongly Agree

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